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A Seven-Day Journal

Stockholm Conference on V.H.F. Sound and Television Broadcasting

A RECENT statement issued by the General Post Office summarises the results of a conference to consider the assignment of very high frequencies (ultra short wavelengths) for sound and television broadcasting in Europe, which began in Stockholm on May 28th. The use of television and very high-frequency sound broadcasting on any appreciable scale by European countries is a comparatively recent development, and the conference, which was convened at the suggestion of the Swedish Administration, was the first of its kind; it was attended by representatives of thirty-one countries. It may be recalled that the world radio conference held in Atlantic City in 1947 allocated three bands of very high frequencies for broadcasting in Europe, namely, 41 to 68 megacycles per second (band I), 87·5 to 100 megacycles per second (band II), and 174 to 216 megacycles per second (band III). The recent Stockholm conference has produced an agreement with which are associated three plans for the assignment of frequencies to European broadcasting stations, one for each of these three bands. In band I the conference accepted the assignments which the United Kingdom has made for the five high-power television stations of the B.B.C., and for the five low-power stations which are to open in due course. The way in which sound and television broadcasting services will develop in the United Kingdom in bands II and III has yet to be decided. But, to secure the most favourable conditions practicable for the future development of United Kingdom radio services in those bands, provisional proposals, for sound and television broadcasting respectively, were submitted to the conference. For band II the delegation sought alternative sets of frequencies for amplitude modulation and frequency modulation, and was successful in securing both sets, as alternatives, in the plan. The agreement has been signed on behalf of the administrations of twenty-one of the thirty-one countries represented at the conference, the non-signatories being Portugal, the U.S.S.R., and eight other Eastern European countries. The United Kingdom delegation signed subject to a formal reservation preserving complete freedom of action for the United Kingdom with regard to the use of frequencies in bands II and III. The Stockholm plans will come into force on July 1, 1953, and are due to be reviewed not later than July 1, 1957.

Report on the Collapse of a Station Footbridge

THE Ministry of Transport has published the report of its inquiry into the collapse of a footbridge, on January 19th last, at Knowaley Street Station, Bury, in the London Midland Region of British Railways. The inquiry was conducted by Brigadier C. A. Langley. A large number of intending passengers were moving slowly over this covered wooden footbridge when the bottom booms and floor fell out, with the result that about 200 people fell approximately 15½ft on to the railway tracks below. Unfortunately, two people lost their lives and 173 others were injured. The report says that the footbridge is believed to have been built about seventy years ago. Its total length was 72ft 6in, though cast iron columns on the up platform of the station reduced the clear span to 60ft 9in, and it was that section of the bridge which collapsed. The main structure consisted of two timber queen post trusses carrying a 4in thick timber flooring on the bottom booms. As a result of the inquiry, Brigadier Langley says that he was satisfied that the footbridge, as designed, was strong enough to carry the heaviest passenger load likely to be placed upon it, and that the failure would have been prevented if the bridge had been maintained in a proper condition. The ends of the down platform side trusses were partially enclosed by a brick abutment so that damp seeped into the timber encased in the bearings and set up serious decay. The failure, the report states, was due to the straps having corroded so badly that they were no longer transmitting any stresses to the rest of the structure. At the end of his report, Brigadier Langley says that, before the accident, regulations for the examination of structures had been revised in the London Midland Region and specially-trained bridge examiners had been appointed. Unfortunately, however, the examiner in the Blackburn district had only just taken up his new duties. The new instructions provide for a three-year inspection cycle for bridges. The report adds that, although many railway structures are getting old, there is no reason on that account to doubt their safety, which has been generally assured throughout the years by careful and regular examination and by the prompt execution of necessary repairs.

A Northamptonshire Water Supply Scheme

THE Mid-Northamptonshire Water Board has approved a scheme, which is estimated to cost about £72,000, for improving its water supply system in nineteen parishes in the western part of its area. The existing system, the Board says, is defective as there is insufficient storage, small sources of supply have been outstripped by the demands made on them, and mains laid about fifteen years ago are inadequate for present needs. Taking into account the needs of the railway at Braunston station, the total daily requirement of water in the area is put at 341,000 gallons. The existing available storage consisting of three service reservoirs, can contain only 380,000 gallons. The scheme now approved provides that the whole of the supply to the area shall, in future, be taken from an existing source at Ravensthorpe, from where it will be pumped through a 10in main which will subsequently divide into two 8in mains. One of the latter will terminate in a new service reservoir to be known as West Haddon No. 2, which will have a capacity of 250,000 gallons, and a top water level 615ft above O.D. A small water tower, with a capacity of 10,000 gallons, is to be built on the same site, water being lifted to it from the reservoir by small automatic pumps. Another service reservoir, with a capacity of 250,000 gallons and a top water level 570ft above O.D., is to be built at Welton to replace an existing small storage tank at Bragborough Hill. The scheme includes also the provision of two small booster pumping stations.

Lloyd's Shipbuilding Returns

THE shipbuilding returns for the quarter ended June 30th have been issued by Lloyd's Register of Shipping. In Great Britain and Ireland, the work in hand consists of 343 steamships and motorships of 2,076,241 tons gross, which represents a reduction of 194,380 tons compared with the previous quarter; of the total 90 ships of 503,901 tons were fitting out and the remainder still to be launched. During the quarter 57 ships of 205,641 tons were commenced, 62 ships of 309,018 tons were launched, and the ships completed numbered 68 of 405,600 tons, while work on four ships was suspended. A total of 95 ships of 627,388 tons was under construction for registration abroad, this being 89,465 tons less than at the end of March last, and represents 30·2 per cent of the tonnage being built. Oil tankers of 1000 tons and upwards, under construction, totalled 100 ships, representing 1,130,486 tons, a decrease of 154,574 tons compared with last quarter's record figure, and 54·4 per cent of the tonnage building. By the end of the quarter, plans had been approved for 321 ships totalling 2,531,623 tons, of which 61·5 per cent were oil tankers. Abroad, 847 steamships and motorships of 3,537,942 tons gross were under construction; this is an increase of 127,995 tons over the previous quarter, and does not include returns for China, Poland and Russia. During the last three months 186 ships of 856,685 tons were commenced, and 182 ships representing 610,351 tons were launched, while completed vessels totalled 202 ships of 728,074 tons, and construction of 69,743 tons of shipping had been suspended. The number of oil tankers building totalled 126 ships of 1,445,899 tons, representing an increase of 237,291 tons over the previous quarter, and 40·9 per cent of the total tonnage being built abroad. A summary of world shipbuilding shows that 1190 ships of 5,614,183 tons gross are under construction, of which 37 per cent is being built in Great Britain and Northern Ireland. The total includes 188 ships of between 10,000 tons and 15,000 tons, 37 ships of between 15,000 tons and 20,000 tons and 18 ships of between 20,000 tons and 30,000 tons each. Oil tankers under construction amount to 226 ships, representing 2,576,385 tons, and 45·9 per cent of world construction. Of the steam and motor ships building throughout the world, 3,641,597 tons, or 64·9 per cent, are under the inspection of Lloyd's Register, of which total 1,970,776 tons are under construction in Great Britain and Northern Ireland, and 1,670,821 tons are building abroad.

Opening of Apprentice School

LAST Friday, we witnessed the opening ceremony of the new apprentice training school at the works of Rolls-Royce, Ltd., Derby. The Rt. Hon. Sir Walter Monckton, Q.C., who opened the new premises, remarked how significant it was that a firm whose name was synonymous with the highest quality in design and workmanship should take such great pains not only in the selection of its designers, but in the training of its craftsmen, which was so apparent in the new school. The new premises house classrooms and lecture rooms and equipment for the instruction of all pupils in machine tools of all basic types, sheet metal fabrication, forging and casting, surface treatment by electrical and chemical deposition, heat treatment and instruction in the skill required to fit and build up an assembly of finished parts. Each apprentice spends twelve months in the school which, at the present stage, is capable of instructing 120 trainees. Over half the time is spent on the machine tools, amongst which are many modern capstan lathes, centre lathes, millers and grinders. Whilst, naturally, no actual engine components are made, jigs, fixtures and equipment to the value of £10,000 have been made and usefully employed. Other aspects of vocational training at Rolls-Royce, Ltd., include its aero engine school, a distinguishing feature of which is the very extensive use of sectioned engine components. To fill another gap in the firm's labour requirements there is a very well equipped drawing office instruction school.

Worm Gear Design

By HARRY WALKER, D.Sc. (Eng.), M.I.Mech.E.*

British Standard Specification 721 *for "Worm Gearing" gives detailed recommendations for the design of worm gears having involute helicoid thread form. The method of design gives satisfactory results for worm gears of low and moderate lead angle, but there is a range of multi-thread worms of high lead angle which is not adequately covered by the specification in that its use could result in designs which do not give the best contact conditions. Experience obtained in the use of the specification since it was published in* 1937 *has also shown the desirability of defining more clearly a method of spacing worm gear designs in such a manner as to reduce the total number of new hobs and tools without over-restricting the choice of available designs. These matters are discussed and proposals are made which, whilst consistent with the original basis of the system, provide simple means for overcoming the difficulties.*

Introduction

By H. E. Merritt, M.B.E., D.Sc. (Eng.) M.I.Mech.E.†

ALTHOUGH rudimentary worm gears were known in the fifteenth century (as shown by an engraving by Durer), and were possibly thought of by Archimedes, their present state of technical refinement has been developed almost entirely in England.

Henry Hindley, clockmaker, of York, invented in 1740 his dividing machine, based on a wheel and "endless screw," and his name is still associated with the "globoidal" type of worm gearing in which the face of the worm is concave and conforms to the periphery of the worm wheel. Around the beginning of the present century, Lanchester applied globoidal worm gears to automobile rear axles; the worm was hardened, but not ground, and the worm wheel teeth were generated by a hob similar in form to the worm. At about the same time worm gears in which the worm was "parallel," i.e., had helical threads, were also applied to rear axles, and were influenced by established practice in the design of screw threads in that the axial profile was straight sided.

In 1915, however, F. J. Bostock, whose work has not been adequately recognised, patented a form of worm gear in which the worm is an involute helicoid. Bostock appears to have been the first to appreciate that high efficiency and load-carrying capacity depend upon both the conditions of tooth engagement and the accuracy of the gears. By using the involute helicoid he arrived at a thread form which could be ground by the plane side of an abrasive wheel, and measured along the straight line of generation; further, by so arranging that the base cylinder of the worm threads was just above the root diameter, and that the pitch cylinder of the worm wheel touched the base cylinder of the worm, he arrived at very favourable conditions of engagement.

Worm gears designed on principles established by Bostock were applicable, however, only to comparatively small ratios of reduction, of the order of 7 : 1 or less, with multi-start worms, and although they were used on a large scale for rear axles, their use could not be extended to many industrial worm drives, the ratios of which commonly range from 10 : 1 to 60 : 1, and sometimes more. The present writer, in 1925 and for a year or two thereafter, pursued the question of applying the involute helicoid worm to the higher ratios, and re-examined the load-carrying capacity of gears having the smaller ratios then usual.

The first conclusion reached, from a study of the zone of contact, was that for worm gears of the smaller ratios the load-carrying capacity could be increased somewhat by displacing the pitch plane, so that it is not tangential to the base cylinder of the worm, but it is distant from it, outwards, by about one-third of the depth of the worm threads. It is probable that this entailed some loss of efficiency, but owing to the difficulty of measuring worm gear efficiency, the effect of the change has never been precisely ascertained.

At the same time, it was obvious that worm threads of involute helicoid form could be ground, using a plane-sided wheel and the settings possible on existing grinding machines, for all lead angles required on high-ratio industrial drives. In such cases, although the theoretical efficiency and load-carrying capacity would not be expected to be any better than those of straight-sided worm threads, the greater ease with which accuracy could be obtained and the improved performance to which that accuracy would probably lead, were arguments in favour of using the involute helicoid.

But before this could be applied to practice it was necessary to decide upon a standardised system of detail design, preferably one which could be applied without discontinuity over the whole range of ratios which might be required. A new system of detail design, termed the "module system," was therefore evolved, and was included in B.S.S. 721, 1937.

This specification, however, was incomplete in that it did not contain information applicable to all designs of worm. The omissions related to those cases in which the lead angle of the worm was comparatively high, when modification became necessary in order to achieve a satisfactory base or root diameter or to prevent the threads from becoming too narrow at the crest. Criticism has also been levelled at the specification on the grounds that the involute helicoidal surfaces of the worm threads are not conjugate to the "basic rack" which now figures in other B.S. gear specifications.

Dr. Walker, however, has now succeeded in devising simple methods which result in satisfactory proportions over the whole range of worm gear design, whilst consistent with the original basis of the system and with the requirements of production.

The involute helicoid thread form, which had previously been a proprietary and patented form for worm gears and made exclusively by one manufacturer, was in 1937 introduced as a British Standard. This bold step has since proved to be fully justified and has undoubtedly helped to maintain the lead which this country has always held in worm gear development.

The introduction of the module system represented a considerable departure from the methods of detail design then applied to worms of the straight-sided type. First, the axial pitch was defined, not by the usual "linear pitch" in binary fractions of an inch, but by the module in inch units. This, of course, is merely the reciprocal of the diametral pitch. The result is to eliminate π from calculations of pitch diameter and centre distance, and although π then enters into the calculation, setting and measurement of axial pitch, it entails no physical difficulty.

Secondly, it was decided to use a limited series of basic forms of worm thread, of unit module (πin axial pitch) which would be applied to different pitches by using the principle of geometrical similarity. This was done by adopting, for each basic form, and unit module, a nominal worm pitch diameter represented by a whole number. This was called the "diameter quotient" and denoted by q. Thus, if q=10, for example, the nominal pitch diameter is 10in for unit module, and is the same as that of a spur gear having ten teeth of unit module or πin circular pitch. For any other pitch, in this example, the nominal pitch diameter of the worm would be the same as that of a spur gear having ten teeth and the same pitch. In general, therefore, taking the worm and wheel together, and denoting the number of teeth in the worm wheel by T, the pitch diameters and centre distance are the same as those of a pair of spur gears having q and T teeth, and the same pitch.

Each value of q is, however, associated with the various possible values for the number of threads in the worm, denoted by t. The shape of any worm, given a standardised system of detail dimensions, is then completely expressed by the "designation," written $t/q/m$, where m is the module in inches.

The analogy with spur gears was carried further by making the addendum of the worm, measured from the nominal pitch diameter, always equal to 1in for unit module. This is the standard value for the addendum of unmodified spur gear; hence, for a given value of q, not only the nominal pitch diameter, but also the outside diameter, are the same as for a spur gear having q teeth and the same pitch.

The choice of 1in for the addendum of the worm, when m=1, was not, however, selected merely for the sake of having this convenient relationship. It was, rather, a fortunate chance, for by using a constant addendum having this value, in conjunction with a depth of thread proportional to the normal pitch, the position of the nominal pitch diameter relative to the crest and root of the thread changes in a convenient manner.

Thus, the working depth of thread, for unit module, was made equal to $2\cos\lambda$, where λ is the lead angle (obtained from the simple relationship $\tan\lambda=t/q$), so that the addendum of the worm wheel is $2\cos\lambda-1$. When λ is small, the respective addenda of the worm and worm wheel are nearly equal, but when λ=45 deg. the addendum of the worm wheel is reduced to 0·414, whilst that of the worm remains at 1in. This gives, in both these extreme cases and in intermediate ones, well-disposed zones of contact.

Given these major dimensions, the form of the involute helicoid which constitutes the surface of the worm thread was determined by making the normal pressure angle equal to 20 deg. at the nominal pitch diameter.

The remaining dimensions were fixed by using a bottom clearance equal to $0{\cdot}2\cos\lambda$ (for unit module) and by making the axial thickness of the worm threads equal to one-half the axial pitch at one-half the total depth of thread.

It is, of course, well known that worms and wheels can be designed and manufac-

* Technical Engineer, John Holroyd and Co., Ltd., Milnrow.

† Chief Administrative Engineer, Humber Limited, Coventry.

tured to work at a centre distance greater or less than the nominal centre distance, and the specification gave (somewhat arbitrarily) $\pm 0{\cdot}25m$ as the limits of extension and closing of centre distance from the basic figure.

The resulting worm proportions given in the B.S. 721 specification can be summarised, so far as relevant to this article, in the following notation and formulæ :—

NOTATION

a=addendum of worm thread.
b=dedendum of worm thread.
c=clearance.
C=centre distance.
d=nominal pitch diameter of worm.
d_o=outside diameter of worm.
d_r=root diameter of worm.
d_o=base diameter of involute helicoid.
L=lead of worm threads.
m=module.
q=diameter quotient.
t=number of threads in worm.
T=number of teeth in wheel.
λ=lead angle of worm threads.
ψ_n=normal pressure angle=20 deg.
λ_o=base lead angle.

FORMULÆ

$d=q \cdot m$.
$\lambda=\tan^{-1}t/q$.
$\psi_n=20$ deg.
$\cos \lambda_o=\cos \lambda \cdot \cos \psi_n$.
$L=\pi \cdot t \cdot m$.
$d_o=L/\pi \cdot \tan \lambda_o$.
$a=m$.
$b=m(2{\cdot}2 \cos \lambda-1)$.
$c=0{\cdot}2\, m \cdot \cos \lambda$.
$d_o=d+2a$.
$d_r=d-2b$.
$C=0{\cdot}5m(T+q) \pm 0{\cdot}25m$.

Axial thread thickness at one-half total thread depth $=\pi \cdot m/2$.

Outstanding Questions.—Experience in the practical use of the specification and the continued development of worm gear technique in recent years have now indicated a number of outstanding questions, to some of which the writer first drew attention in 1946 :

(1) With the proportions stated above, it is found on certain worms in which λ is large and q is small, that the base diameter can exceed the root diameter by more than two clearances. This results in undesirable

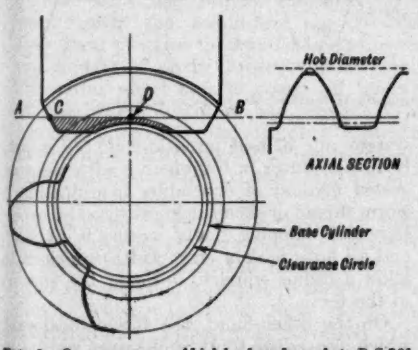


FIG. 1—*On some worms of high lead angle made to B.S.721 proportions, the base circle diameter may be larger than the clearance circle, giving an area of undesirable contact on the wheel addendum, which is shown shaded. The example above is for a 5-thread worm with* q=6

contact conditions in that it leaves a useless portion of the worm wheel addendum and may also result in undercutting of the worm threads. By way of example, Fig. 1 shows sections of a worm having five threads and a diameter quotient equal to 6, proportioned according to the formulæ given in B.S. 721. AB is a plane tangential to the base cylinder, and this intersects the thread surface on a generator CD inclined at the angle λ_o to the plane of the diagram. The obliquity of the worm thread at all points on the line CD is zero, and consequently the shaded portion of the wheel addendum is useless for contact purposes. A five-thread worm with a diameter quotient as low as 6 is not very frequently used in practice, but the example has been chosen to illustrate an extreme case. Some, but not all, of those worms in which the base circle is greater than the clearance circle, are also defective in that the crest width of the corresponding hob for the worm wheels is too narrow to permit the desired radius on the corners of the hob teeth.

Some gear manufacturers have hitherto made their own arrangements for avoiding these difficulties, but there is justification for a method to be stated in the specification so that any designer (not necessarily versed in gear technique) can start on the correct lines. Once a design is completed there is sometimes a resistance to alterations which

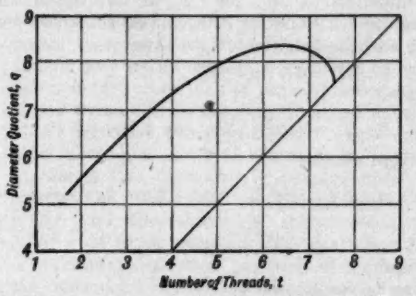


FIG. 2—*Graph showing for various numbers of threads the minimum value of* q *below which the base circle diameter is greater than the clearance circle diameter*

may be suggested by the gear manufacturer who frequently enters the picture only after it is too late to accept his modification.

(2) The rule for thread thickness, "half pitch at half full depth," gives a satisfactory relationship between the respective thicknesses of the worm threads and the worm wheel teeth, but it results in normal basic racks which are not geometrically similar for different values of λ. Other B.S. gear specifications, however, incorporate the conception that all teeth have forms capable of generation from a normal basic rack of constant proportions. It is for consideration whether this conception can or need be applied to worm gears. A positive answer would raise the further question as to whether the rack form should be identical to that used in B.S. 436 for spur and helical gears, or whether the special needs of worm gearing call for other proportions.

(3) A question in regard to diameter quotient is whether the recommended integral values are adequate to cover all designs or, alternatively, whether intermediate values are desirable from the point of view of standardising a minimum number of worm sizes.

(4) Finally, the problem arises of the extent to which it is practicable to standardise the form of worm threads in a range of defined sizes as distinct from standardised rules for detail design. The purpose of standardising a range of defined sizes would be to minimise the required number of new tools and hobs, by spacing the designs in a manner likely to cover all requirements and yet ensuring that the sizes are not so closely spaced as to make their number unnecessarily large. Here, again, some manufacturers of worm gearing have attempted to work to their own conception of a spaced pattern of worm gear designs, but it is thought that there is now need for a common statement of purpose and method. This should preferably be available to the gear user or the gear designer in the original design stages and should therefore appear in the specification.

Proposals in connection with these problems are here offered.

LOCATION OF BASE CIRCLE AND ROOT CIRCLE

The graph in Fig. 2 shows for each number of threads in the worm the value of q below which the base circle diameter exceeds the root diameter by more than two clearances. This is based on the existing proportions of B.S. 721. Those combinations of t and q lying below the curve require special treatment to avoid undesirable thread and tooth forms.

In his book *Gears*† Dr. Merritt gives the formulæ which can be applied to worm thread dimensions when modification is required for base diameter or hob crest width. These are based on an increase of normal pressure angle on the nominal worm pitch diameter, the amount being calculated to make the base diameter coincide with the root diameter determined from the proportions of B.S. 721, or with an enlarged root diameter if this is required in order to maintain the crest width. Alternatively, the standard root diameter could be maintained and the threads "topped" where necessary to increase the crest width.

A simplification of this method is now suggested, which seems to be well suited to the purpose of standardisation because it maintains the present standard normal pressure angle of 20 deg. and combines with it the idea of a normal basic rack of constant proportions, thus bringing it into line with the other gear specifications. It can, moreover, be conveyed in a specification in a few brief paragraphs and requires no tedious calculations in determining worm gear proportions. It also avoids the complication of "topping."

A decision must first be made as to a suitable limiting position of the base circle relative to the root circle. Practical manufacturing requirements are fulfilled if the base circle is not greater than the clearance circle, and this limiting position also offers the greatest possibility of using for contact purposes a maximum depth of thread. It is therefore suggested as a working basis that all worms in which the base circle diameter would otherwise be greater than the root diameter plus two clearances, should be subject to modification in such a manner that the base circle coincides with the clearance circle.

The chart, Fig. 3, shows the amount by

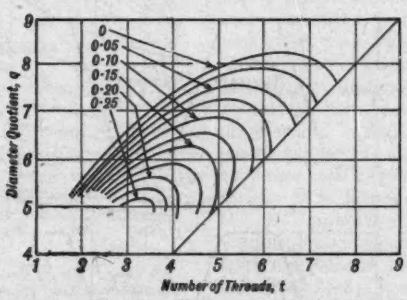


FIG. 3—*Chart of dedendum modification factors* k, *for all combinations of* t *and* q

which the base circle radius exceeds the clearance circle radius, for all worms made to the present B.S. 721 proportions and for 1in module. These values, which will be denoted by k and termed the "dedendum modification factor," are calculable from :

$$k=2 \cos \lambda-1-\tfrac{1}{2}(d-d_o)$$
$$=2 \cos \lambda-0{\cdot}5q(1-\cos \psi_t)-1,$$

where

$$\tan \psi_t=\tan \psi_n \cdot \operatorname{cosec} \lambda.$$

With the principle now suggested, all

† Sir Isaac Pitman and Sons, first and second editions.

worms would be derived from a normal section basic rack of 20 deg. pressure angle and a working depth of $2m \cdot \cos\lambda$. (The proportions for clearance and relative tooth to space thicknesses are discussed under a later heading.) Worm threads not requiring modification would be derived by using the counterpart basic rack at the full depth of engagement with the worm. All those worms requiring modification would be derived from the same counterpart rack, but the depth of engagement with the worm would be reduced by the amount $k \cdot m$, so that the root circle is increased until it is radially one clearance from the base circle. The

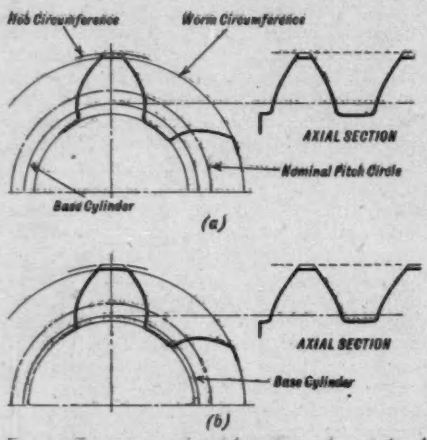


FIG. 4—*Transverse and axial sections of a 5-thread worm, before and after modification*

addendum of the worm remains at its fixed value m.

This in effect is equivalent to a reduction in dedendum, as applied in ordinary gear correction for interference and undercutting, but without the corresponding increase in addendum. Fig. 4 shows the change in the transverse and axial sections of a five-thread worm with q equal to 6, resulting from the modification. In the upper illustration are shown the original proportions of B.S. 721 for 1in module and below are the proportions resulting from withdrawing the cutter (or counterpart basic rack) by the amount k, which for this example is 0·145in. The base cylinder now coincides with the clearance cylinder and the thread thickness is increased owing to the withdrawal of the basic counter-

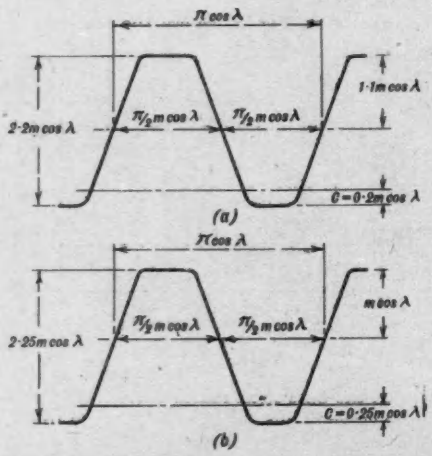


FIG. 5—*The upper diagram (a) shows the proposed normal section basic rack having equal tooth and space thicknesses at half the full depth and a clearance of 0·2m cos λ. The lower diagram (b) shows the basic rack for helical gears used in B.S. 436*

part rack. It will be seen from the values of k in Fig. 3 that as q diminishes there is a progressive reduction in thread depth, which in the extreme case of a q value as low as 5·0 varies according to the number of threads from 8 to 15 per cent of the original thread depth. This reduction in thread depth fortuitously occurs on all those worms that might otherwise require "topping" to maintain adequate hob crest width, and it is therefore to be observed (bearing in mind that the base circle lies on the clearance circle) that a maximum thread depth consistent with the use of 20 deg. pressure angle, is made available for contact.

With a basic rack of constant proportions on the normal section, caliper settings are easier to calculate than they were with the original rule of half axial pitch at half-full depth. If we assume for the time being the same normal basic rack as is used for helical gears, the constant chord, for an unmodified worm, is represented by CD in Fig. 6*a*, which shows the normal basic rack proportions, of thickness $\pi \cdot m \cdot \cos\lambda/2$ at a depth of $m\cos\lambda$. Denoting the caliper thickness by g and the height by h we have :—

$$g = CD = AB \cdot \cos^2\psi_n$$

and

$$AB = \frac{\pi}{2} \cdot m \cdot \cos\lambda + 2m \cdot \tan\psi_n(1-\cos\lambda),$$

from which

$$g = m\left\{\frac{\pi}{2} \cdot \cos^2\psi_n \cdot \cos\lambda + 2\tan\psi_n \cdot \cos^2\psi_n (1-\cos\lambda)\right\},$$

and

$$h = m - \tfrac{1}{2}g \cdot \tan\psi_n.$$

For modified worms the basic rack (cutter) is withdrawn from the worm by a distance km, as shown in Fig. 6*b*, and consequently the thickness setting is increased by $2TP$, i.e., by

$$2k \cdot m \cdot \sin\psi_n \cdot \cos\psi_n.$$

The height setting is reduced (since the worm addendum remains equal to m), by TR, i.e., by

$$k \cdot m \cdot \sin^2\psi_n.$$

Anticipating the use of integral and demi-integral values of q, as discussed later, the practical design method of obtaining the worm gear proportions may be presented as follows :—

The existing formulæ for worm gear proportions in B.S. 721 remain as already quoted, with the exception of the formula for worm dedendum b and the rule for thread thickness.

The formula for worm dedendum becomes

$$b = m(2\cdot2\cos\lambda - 1) - k \cdot m$$

and constant chord caliper settings (for a normal pressure angle of 20 deg. and the B.S. helical rack thickness proportions) are

$$h = m(0\cdot883 - 0\cdot135\cos\lambda - 0\cdot117k)$$
$$g = m(2\cdot03 - 0\cdot643\cos\lambda + 0\cdot643k)$$

In both of these formulæ k is equal to 0, except in those cases where the value of q corresponding to the number of threads is less than that given in the last vertical column of the table below. In such cases k is read from the table.

The numerical constants in the formulæ for caliper settings would be altered if the normal basic rack suggested later is adopted.

Basic Rack Proportions

Quite apart from any academic advantage, it now seems certain that a basic rack of constant normal proportions is more practically fitted to the design of worm gearing than is one of variable proportion. A working depth identical to that in the helical gear specification (i.e., $2m \cdot \cos\lambda$) is also satisfactory for worm gearing. The questions of the relative tooth to space width and the magnitude of the clearance are, however, debatable and show two clearly divided opinions, one of which holds that the proportions should be those which best serve the particular requirements of worm gearing, and the other holds that the proportions should be exactly the same as for helical gears, partly for the sake of consistency and partly with the thought that hobs made to the B.S. specification for spur and helical gears might be used for rough cutting the worm threads.

A normal basic rack having equal tooth and thread thicknesses at half the full depth ($2\cdot2m \cdot \cos\lambda$) and a clearance of $0\cdot2m \cdot \cos\lambda$, as shown in Fig. 5*a*, would result in a thread thickness hardly different from the thread thickness obtained from Dr. Merritt's module system rule of half pitch at half full depth. It also produces in conjunction with the suggested method of dedendum modification a worm thread of such thickness that the necessity for "topping" any worms is avoided and all hobs have a crest width sufficient to allow a radius equal to $0\cdot75c$ at the corners of the teeth.

On the other hand, the B.S. helical rack which has equal tooth and space widths at mid-working depth and a clearance of $0\cdot25m \cdot \cos\lambda$, as illustrated in Fig. 5*b*,

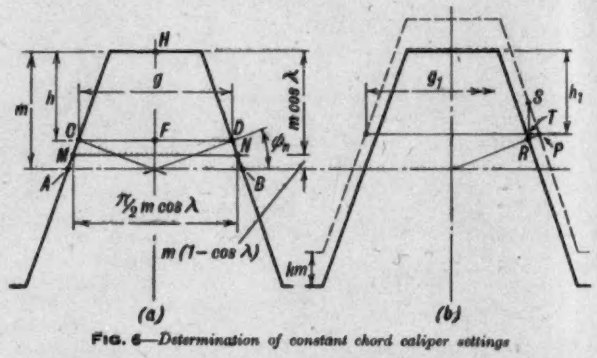


FIG. 6—*Determination of constant chord caliper settings*

Table of k Values

No. of threads t	q							Value of q below which dedendum modification is required
	5·0	5·5	6·0	6·5	7·0	7·5	8·0	
2	0·143	0·012	—	—	—	—	—	5·5
3	0·256	0·195	0·115	0·018	—	—	—	6·6
4	0·221	0·205	0·173	0·124	0·058	—	—	7·4
5	0·136	0·150	0·145	0·126	0·095	0·050	—	8·0
6	—	—	0·081	0·083	0·073	0·051	0·021	8·3
7	—	—	—	—	0·025	0·020	0·007	8·2

gives in comparison a somewhat thinner wheel tooth and 25 per cent greater clearance. It is suggested that such a basic rack, whilst maintaining some degree of consistency‡ with helical gears, is not as serviceable (for worm gearing) as the one defined in the previous paragraph for the following reasons :—

(1) It is logical that the worm threads, being made of case-hardened steel, should be kept to a minimum practical thickness in order that the phosphor-bronze wheel teeth

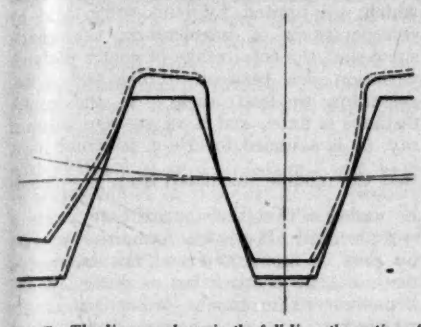


FIG. 7—*The diagram shows in the full lines the section of a wheel tooth in engagement with the proposed basic rack of Fig. 5(a). The broken lines show for comparison purposes the effect when using the helical basic rack of B.S.* 436

of weaker material and more subject to wear, may be as thick as possible.

A wider worm thread space has two further advantages. First, it helps to avoid difficulties in the thread grinding operation on small pitches due to crumbling of a grinding wheel which is too narrow at the point, and, secondly, it permits a somewhat wider extension of centres on certain wheels with low numbers of teeth where the limiting factor is the land width at the top of the wheel tooth. Fig. 7 shows the proposed normal basic rack in engagement with a wheel of thirty teeth. In order to show by comparison the differences indicated above, the broken lines have been added, showing the change in profiles which would result from using the B.S. helical rack. The differences in thickness and clearance, although not great, are clearly distinguishable.

(2) On helical gears a clearance of $0{\cdot}25m \cdot \cos\lambda$ has proved desirable. With worm gears the conditions are different. It is good practice to chamfer or radius the top corners of worm threads and to permit the worm wheel hob to round off the tips of the wheel teeth at the throat. This virtually increases the running clearance so that an initially large clearance is unnecessary. Helical gears do not call for such chamfer or radius.

A limiting factor in the design of worm gears is created by the stiffness of the body of the worm beneath the threads. Helical gears are not usually subject to such a limitation. Bearing in mind that stress and deflection are respectively inversely proportional to the root diameter, a larger clearance than is practically necessary is undesirable.

(3) The B.S. helical basic rack, if applied to worms, would make obsolete all existing worm wheel hobs made to B.S.S. 721. The alternative basic rack as proposed would only rule out those hobs whose worm designations fall within the "modified area"; all other hobs would be usable since the slight change in thread thickness from the original specification is easily absorbed within the backlash tolerance of the finished gears. The change in thread thickness referred to is negligible on worms of low lead angle since when $\lambda=0$ there is obviously no difference. It increases with the lead angle and for worms approaching the modified area it amounts to about $0{\cdot}01m$.

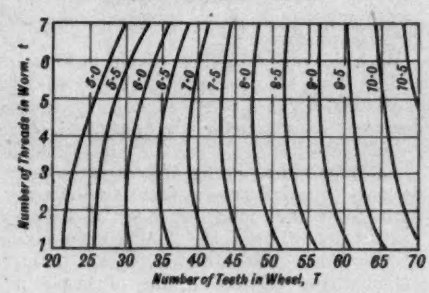
‡ There is still a definite inconsistency in that if hobs corresponding to the basic helical rack are used for cutting worms, the final thread thickness is reduced by thread grinding, thus creating a difference in thickness from the basic rack form.

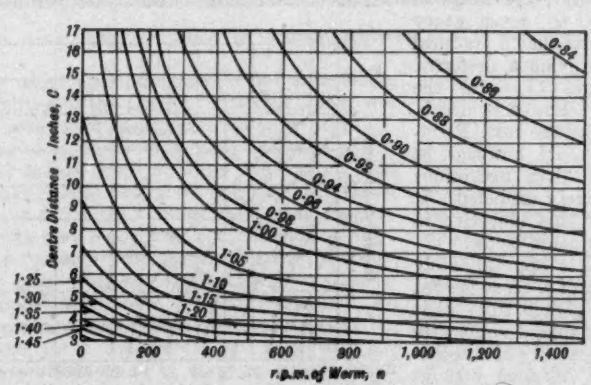
Minimum Values of q

Worm gears become more efficient as the lead angle increases towards 45 deg., and for maximum efficiency q should therefore be as small as possible provided it does not become less than t (when $t=q$, $\lambda=45$ deg.). For a given centre distance, the load capacity also becomes greater as q decreases, because the load capacity increases in approximately direct proportion to the wheel diameter. A requisite of good worm gear design is therefore to give q its smallest value. It should not, however, be less than what will ensure adequate stiffness and strength to the body of the worm.

In practice, a worm of 2 or 3 per cent nickel case-hardening steel is found to be satisfactory if the deflection does not exceed about 0·004in per inch of root diameter, and if the stress due to bending does not exceed about 15,000 lb per square inch. If we consider a circular shaft of diameter d_r loaded at the centre between bearings distant S apart, the deflection is proportional to S^3/d_r^4 and the stress is proportional to S/d_r^3. If for a series of such shafts we fix a maximum deflection per inch of diameter, the maximum stress will therefore be proportional to d_r^2/S^2. Thus, if d_r/S is constant over the series of shafts, the stress corresponding to a deflection made in a fixed proportion to d_r will be constant.

In worm gear design the ratio of root





FIGS. 8 AND 9—"*Ratio Factor*" *and* "*Centre Distance Factor*" *used for determining minimum value of* q *for adequate strength and stiffness of the body of the worm*

diameter to worm bearing span is not quite independent of centre distance, there being a tendency, due to ball bearing dimensions, to a relatively wider span on smaller centre distances. The relationship between deflection per inch of diameter and bending stress does, however, hold good very approximately, and if a basis of a maximum deflection of 0·004in per inch of root diameter is selected, the corresponding stress is about 14,000 lb per square inch.

On this basis, and for gears loaded in accordance with the specification, charts Figs. 8 and 9 have been prepared from which it is possible to determine approximately the minimum value of q for adequate stiffness and strength. The charts enable a "ratio factor" and a "centre distance factor" to be obtained, which, when multiplied together, give the minimum value of q. For example, assume a pair of gears of 4/46 ratio at 7in. centres with a worm speed of 1000 r.p.m. Then q (minimum) is

$$7{\cdot}8 \times 0{\cdot}97 = 7{\cdot}6.$$

The method involved in making the charts necessarily includes some approximations and assumptions. The span of the worm shaft bearings was taken from actual practice obtaining in a maker's range of totally enclosed worm reduction units, ball bearing mounted; a basic wheel shaft torque was calculated for each centre distance and modified for worm speed by a curve of constant form for each centre distance. In spite of these approximations, the results are reasonably accurate and give a guide for a first approximation to the minimum q value. In the above numerical example, in which q (minimum) is 7·6, a q value of 7·5 should not be adopted without a final check for deflection and stress. A q value of 8·0 should, however, be safe, since a small increase in q, to which root diameter is approximately proportional, results in a relatively large reduction in stress and deflection.

The same charts may without any change be used as a guide to the value of q even when the worm is in other material than case-hardened steel. If a soft steel of lower tensile strength is used, the allowable working load on the gears from such material will be less, and consequently the deflection and bending stress will automatically be lowered to a safe value.

Standard Range of Designs

Any attempt to standardise worm gear designs in a prearranged pattern of defined sizes must include a sufficient number of sizes to cover all reasonable practical requirements. It is as well, therefore, first to inquire what is meant by reasonable practical requirements.

For the majority of new worm gear designs there is more or less complete freedom of choice in regard to ratio, centre distance and overall worm and wheel dimensions. Given this normal latitude in design, it would be possible to standardise quite a small range of sizes to cover all requirements. It is, however, to the minority of designs, where restrictions are present, that one must look for an evaluation of the requirements in coverage of a standard range.

A review of 1000 consecutive orders for totally enclosed worm reduction units shows that in 945 cases a reduction ratio selected from the following "standard" ratios :—

7 10 15 20 25 30 40 50 60

could be adopted. In the remaining fifty-five cases a particular "non-standard" ratio was stipulated. It seems reasonable that these 5 per cent of cases should be covered by any standardised range of designs, and the first conclusion is that in selecting the spacing

of a range of designs one cannot rely overmuch on being able to manipulate the ratio. Many other examples of worm gear applications in which the ratio is fixed could be cited, e.g., automobile rear axle gears, timing gears, wire-drawing machinery.

The remaining limitations in design are usually the outside diameter of worm and overall diameter of wheel. In automobile gears several ratios have often to be fitted at a fixed centre distance, with a limited overall diameter of wheel, and a worm which must not be so large as to give insufficient strength of wheel rim on a fixed size of differential unit, and yet large enough to give adequate rigidity at the root.

Standardisation must not neglect economy and manufacturing simplicity, which in practice often conflict with considerations based purely on the best design. Examples of this nature occur in those applications already mentioned, where a number of different ratios have to be used in a common design of housing. Totally enclosed "standard" worm reduction units, now made in large quantities by a number of manufacturers, provide a particular application in which manufacturing considerations have to be given some preference. In most of these units a centrifugally cast phosphor-bronze wheel rim is secured to a cast iron centre. For a given centre distance it is a manufacturing and routine simplification to make all the wheel rims of the same overall and internal diameter, irrespective of ratio, and to make all worms from identical forgings or stampings. This method can, however, only be economical if the throat diameter of wheel and outside diameter of worm are very nearly alike for all ratios, as otherwise there would be a wastage of metal in having to provide one size of wheel casting and worm blank to cover widely varying dimensions. The restriction leaves very little latitude in dimensions of worm and wheel, but if there is a sufficient range of design sizes from which to choose, it can be met by absorbing small dimensional differences in the depth of throating of the worm wheel and in the machining allowance on the worm blank.

The only conclusion to be arrived at seems to be that an impractically large range of sizes would be required to cover every possible case, and it suggests that a practical procedure would be to provide a preferred standard range of designs to cover the majority of requirements, followed by a sub-standard to cover nearly all the rest. Formulæ for the general case should, however, be clearly stated in order that exceptions (though rare) are not entirely excluded. It is with the fulfilment of this objective in mind that suggestions are made below.

The diameter of worm is approximately settled by the chosen value of q. A suggested limited range of q values should from what has already been said be spaced sufficently closely to allow interchangeability of different ratios at a given centre distance without big changes in worm or wheel diameter. B.S.S. 721 recommends (without special emphasis) the use of integral values of q. It is now suggested that q values rising in stages of 0·5 (in the lower range of q) are necessary to cover a satisfactory range of designs, and experience over many years has confirmed this. It is therefore suggested that q should be selected from :

5·0 5·5 6·0 6·5 7·0 7·5
8·0 9·0 10·0 12·0, &c.

In conjunction with a range of q values, the formulation of a series of standard modules would completely define the space pattern of standard worm designs for each number of worm threads. B.S.S. 721 does not suggest any standard range of preferred modules and some manufacturers have hitherto made their own internal arrangements, but the designer (often entirely dissociated from the manufacturer) has not always been aware of such arrangements.

The selection of a recommended range of modules depends partly on the allowable extension and closing of centres. The B.S. specification suggests that in all cases a change in basic centre distance of $\pm 0{\cdot}25m$ is permissible. (This is, of course, equivalent to changing the module for a fixed ratio and centre distance by varying the relative position of the pitch plane.) It is now suggested that permissible variations of

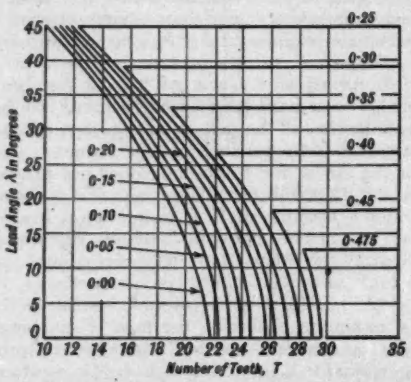


FIG. 10—*Maximum reduction of basic centre distance for 1 module*

centre distance (or module) should be more precisely stated because this becomes of great importance if a range of modules is to be standardised.

With this object in view, graphs in Figs. 10 and 11 have been prepared to show what is considered to be a practical range of centre distance variation for the purposes of a standard.

The maximum closing of centres is based on two considerations : first, an arbitrary limit from the point of view of keeping contact away from the interference point of the worm wheel and also not unduly reducing the relative radius of curvature on the contact lines, is fixed by not permitting

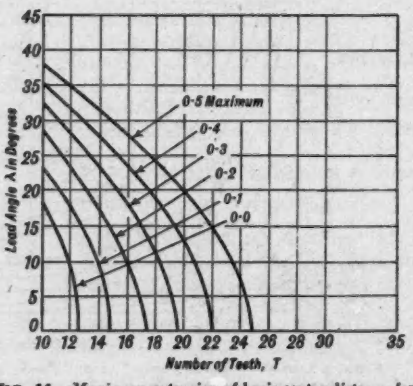


FIG. 11—*Maximum extension of basic centre distance for 1 module*

the outside diameter of the hob to pass beyond a chosen distance from the interference point. Secondly, on worms of high lead angle, the pitch plane must not approach too close to the base circle because it would create practical difficulties in attaining the precise contact in respect to entry gap and leaving side contact which is desired in worm gearing. Modern methods of hob design give a nicety of control over the contact which tends, however, to be lost if the pitch plane is very close to the base circle.

Maximum extension of centres is also based on two limiting factors : first, the wheel teeth at maximum extension must have a sufficient land width at the tips in a central plane such that the profiles would not come to a point if extended one clearance radially beyond the throat ; secondly, a conservative overriding limit of $0{\cdot}5m$ is fixed beyond which it is thought that the performance of the gear might begin to suffer.

If we neglect low numbers of wheel teeth which are limited by land width and by considerations of interference, the charts show that the total range of centre distance variation lies between $0{\cdot}75m$ and $1{\cdot}0m$, according to lead angle. If the centre distance is fixed, and if an average value of say, 50 is assumed for $T+q$, it would mean that the module calculated from $\frac{C}{T+q}$ could be varied within the approximate limits of ± 2 per cent. If q is also permitted to vary by plus or minus 0·5 and the number of teeth can be changed up or down by one, a module within about ± 5 per cent can be selected.

The implied suggestion of a series of standard modules rising in geometrical progression would, however, result in a large number of modules on the smaller pitches, and as there is usually by comparison more latitude in design on small-pitch worm gears, a compromise is suggested in which the modules rise by equal intervals of 0·02 with the possibility of using a module midway between two standards, as a sub-standard mainly intended for small pitches. Thus, round about the popular sizes from 0·25 to 0·4 module, the standards would be :

0·24 0·26 0·28 0·30 &c

and the sub-standards :

0·25 0·27 0·29 0·31 &c.

In rare cases, special modules other than the above would have to be used, but this would create no design difficulty as the general formulæ are clearly stated.

The suggestions outlined above give a latitude for design which will cover practically every possible requirement. There are, however, numerous applications of worm gearing in which highest performance is not important and in which there is some freedom of choice in regard to ratio, centre distance and relative worm and wheel diameters. To meet these everyday requirements with a minimum number of tools, it might prove practicable to include in the appendix to the specification a brief list of designs (i.e., a list of selected combinations of t, q and m from the general standard), which whilst not covering anything like the full range of designs which the specification permits, would be sufficient to cover a large number of ordinary worm gear requirements.

FUEL EFFICIENCY REFRESHER COURSE.—In order to give works engineers throughout the Eastern region an opportunity to obtain up-to-date information about the efficient utilisation of heat and power, a refresher course is being organised by the Ministry of Fuel and Power at the Cambridge University Engineering Laboratories from September 22nd to 26th. It will be the first time such a course has been held in the Eastern region. The course will include a number of lectures by specialists and the subjects to be dealt with include steam, gas and electricity utilisation ; economical use of compressed air ; application of heat pumps and gas turbines ; insulation of buildings and hot surfaces ; boiler plant operation and instrumentation ; refrigeration plant usage ; heating, hot water supply and ventilation ; boiler feed water treatment and self-generation of electricity and use of exhaust steam. Further information concerning the course can be obtained from the Fuel Efficiency Secretary, Ministry of Fuel and Power, Brooklands Avenue, Cambridge.

Present-Day Locomotive Working in Great Britain

No. VII*—THE GRESLEY "PACIFICS" ON THE EAST COAST ROUTE—PART II

By O. S. NOCK, B.Sc., M.I.C.E., M.I.Mech.E.

(*Concluded from page 80, July 18th*)

The day-to-day running of the Gresley "Pacifics" on the L.N.E.R. in the years 1932–39 was an outstanding feature of British locomotive working before the second world war. Extreme difficulties in operation developed during the later years of the war, due to unprecedented loading, and as a result of maintenance troubles the L.N.E.R. decided not to perpetuate the Gresley front end in post-war locomotives. Nevertheless, the Gresley "Pacifics" collectively still continue to do very fine work on the road, and in this article some post-war experiences with the "A4" class are summarised.

THE "A4" class was designed and built at top speed in the year 1935, specially to run the "Silver Jubilee" express. In his presidential address to the Institution of Mechanical Engineers in October, 1936, Sir Nigel Gresley recorded with pride that his staff had carried through the entire job, engines and carriages, in the remarkably short time of five months. Apart from the spectacular appearance of the "A4" engines, due to streamlining, the main differences from the "A3" class lay in the higher boiler pressure, smaller cylinders and a reduced distance between the tube plates. Furthermore, the piston valves were increased from 8in to 9in diameter, and the high finish given to surfaces of steam passages and ports assisted the free flow of steam. The result was seen in the very first high-speed run attempted with an "A4." Whereas in the trials of March, 1935, it needed a good deal of coaxing to get the "A3" engine "Papyrus" up to 108 m.p.h. on the descent from Stoke Tunnel towards Peterborough, the first "A4" attained 112½ m.p.h. with an ease that proved disconcerting to the invited guests of the L.N.E.R. travelling in the train. A very much higher maximum speed was attained on a test run three years later.

But the "A4" was a true development of the earlier Gresley "Pacifics." Two sets of valve gear were used for actuating the valves of the three cylinders, and the conjugated motion used for the inside valve received its most severe test so far in the regular attainment of such high speeds as were demanded in the operation of the "Silver Jubilee" train. As vehicles the Gresley "Pacifics" must be among the best riding engines in the country, and it was the exemplary behaviour of "Silver Link" at continuous speeds of 100 m.p.h. and more on the Jubilee trial trip in September, 1935, that gave no clue to those on the footplate as to how excessively lively had been the riding of the articulated coaching stock behind them. The fine riding qualities of the Gresley "Pacifics" were not achieved without considerable experimenting. Originally, the middle pair of coupled wheels had helical springs, while the leading and trailing pairs had plate springs; the riding did not satisfy Gresley, and some experiments were made with compensated springs. The present arrangement, with uncompensated plate springs for all three pairs of coupled wheels was eventually adopted. An important factor is the side control on the bogie, for if this should be inadequate the Cartazzi slides of the carrying wheels under the firebox provide little or no restraining influence against lateral nosing which can develop into a disconcerting swing. While the riding qualities of individual engines of the "A4" class vary the general standard is high, and any nosing or rolling is almost immediately damped out.

In pre-war years, during the lifetime of Sir Nigel Gresley, the condition of these engines was carefully watched over and it was usually possible to maintain them on the highest class of express passenger service to the time they were sent to plant for general overhaul. During the war it was not possible to give such close attention, and at one time the Gresley three-cylinder engines collectively were in some danger of falling into a degree of disrepute due to the failures of the conjugated valve gear. But in 1945 when I made my first post-war footplate journeys on "A4s," the work was in many ways so outstanding that one could be inclined to regard the maintenance troubles of the war period as a phase that would pass. When the time came for the interchange trials in 1948 engines of the "A4" class were chosen to represent the Eastern Region in the express passenger tests, but the fact that no fewer than three failures due to overheated centre big-ends occurred can be attributed to factors other than the conjugated valve gear. At the speeds normally run at the locations where the failures took place, overrunning of the centre valve spindle would not be sufficient to cause a serious difference between the indicated horsepower developed in the outside cylinders and the inside one.

Some values of drawbar horsepower recorded at various speeds during the interchange trials of 1948 are given in Table IV; they show the kind of road performance that can be expected from the "A4" engines. In each case the values are those of "equivalent" drawbar horsepower, after correction has been made for gradient. The individual points when plotted as graphs are very scattered, and indicate the variation in power output under apparently similar running conditions that are often to be observed in the results of variable speed road tests. In the report of the Locomotive Testing Committee there is only one reading at a cut-off as low as 18 per cent, though these engines are regularly operated at much shorter cut-offs. Observations made on footplate journeys during 1951 indicated lengthy periods run between 10 and 15 per cent on engines that were very well tuned up, and on which there would be less likelihood of false cut-off readings than on units with a high mileage in common-user service to their credit. In general, the "A4s," like the majority of Sir Nigel Gresley's express engines, are run with the regulator wide open wherever possible, and full advantage is taken of the high steam pressure available in the boiler. The economical performance of these engines was underlined in the interchange trials of 1948, when the overall consumption of coal per drawbar horsepower was the lowest of all the competing engines, namely, 3·06 lb per hour.

In 1945, some footplate journeys were made by the author with "A4" class engines on East Coast trains of typical wartime loading, on one of which trouble was experienced with indifferent steaming. This journey, from York to Newcastle, was

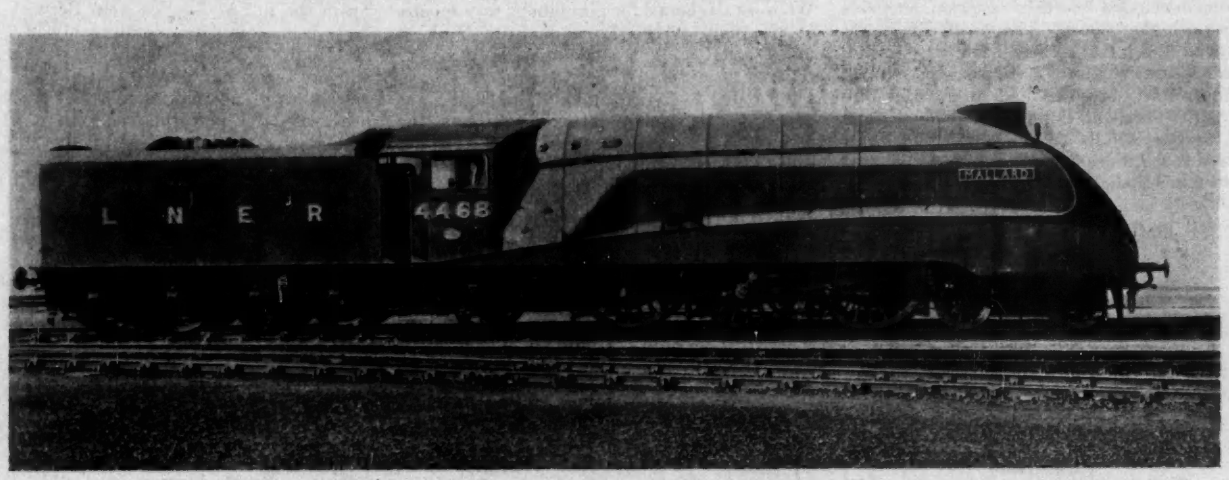


FIG. 5.—CLASS "A4" ENGINE "MALLARD." HOLDER OF WORLD RECORD FOR STEAM TRACTION

* Previous articles in this series were: No. I, "The L.N.E.R. 2–6–2 'Green Arrow' Class," October 11, 1946; No. II, "The L.M.S.R. 'Coronation' Class 'Pacifics,'" December 13 and 20, 1946; No. III, "The G.W.R. Oil-Fired 4–6–0s," February 6 and 13, 1948; No. IV, "The Mixed Traffic 4–6–0s," November 4, 11, 18 and 25, 1949; No. V, "The Western Region 'Castle' Class," April 20 and 27, 1951; No. VI, "First Results from the 'Britannias'," April 4, 1952.

however, a most remarkable exposition of the power these engines normally have in reserve; over 30 miles of gradually rising gradient from Alne to Croft Spa an average speed of 59 m.p.h. was maintained with a load of 610 tons behind the tender, even though boiler pressure was no higher than

engine "Golden Eagle," which had worked through from Peterborough (192 miles), was relieved by another "A4," the "Kingfisher," in first-class mechanical condition and steaming well. But drizzling rain showed up a weakness of this class which seems inherent in nearly all "Pacifics" of British

the 66·9 miles from Newcastle to Berwick-on-Tweed were covered in 82¼ min, or in 75 min net—an average speed of 53·5 m.p.h., and on the continuation to Edinburgh the first 48 miles, to Prestonpans, took 57½ min, including the long climb to Grantshouse up which we made so inauspicious a start from

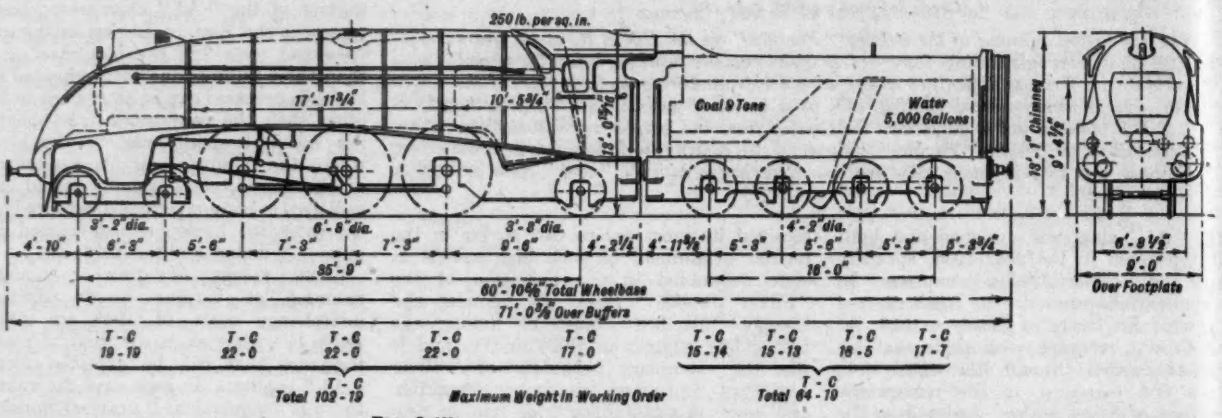


FIG. 6—WEIGHT DIAGRAM OF CLASS "A4" ENGINE

135 lb to 145 lb per square inch. The cut-off was shown as 12 per cent, though the power developed on this occasion suggests a rather higher figure. The start from York, on dead level track, had been very rapid. Boiler pressure was 250 lb per square inch at the outset, but this had fallen to 180 lb per square inch at Beningbrough, 5·5 miles out, and to 175 lb at Tollerton. The latter station is 9·7 miles from York; it was passed in no more than 12¾ min from the start, and the speed had by then reached 68 m.p.h. The fall in boiler pressure caused a steady

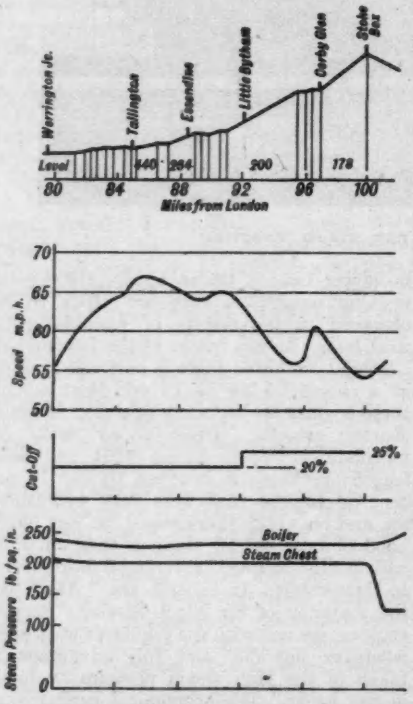


FIG. 7—PERFORMANCE OF ENGINE No. 60,030

falling off in the speed, to a general average of 60 m.p.h. north of Tollerton. The complete run of 80·1 miles from York to Newcastle was completed in 94 min, a gain of 6 min on the schedule then in force; this included relatively slow running through the Durham colliery districts, as well as the usual 30 m.p.h. slack through Durham itself.

At Newcastle, on this same trip, the

design—their susceptibility to slipping. It is true that conditions were unfavourable. We were slackened for permanent way repairs at the foot of the Longhoughton bank, 4 miles at 1 in 170, and in attempting to recover from a speed restriction to 25 m.p.h. right at the foot of the incline the engine was slipping at frequent intervals through the ascent. The average speed over the 4·8 miles between Alnmouth Junction and Little Mill stations was only 27·8 m.p.h. Cut-off

Berwick. A succession of checks hindered the approach to Edinburgh, but with a normal finish the full 57·5 miles from Berwick could have been completed comfortably in 70 min or 71 min. The susceptibility of the engine to slip on a wet rail prevented the speed being worked up against moderate gradients; otherwise the performance with a 610-ton load was of much the same quality that was needed in pre-war years to maintain booked average speeds of 60 m.p.h. over the 105·5

TABLE IV—*Performance of "A 4" Engines in 1948—Interchange Trials*

Region of test	Cut-off, per cent	Steam chest pressure, lb/sq in	Speed, m.p.h.	Equivalent drawbar pull, tons	Equivalent drawbar horsepower	Engine concerned
Midland	18	195	59·2	3·1	1084	"Lord Faringdon"
Midland	20	207	44·6	4·1	1090	"Lord Faringdon"
Midland	20	215	64·1	3·6	1393	"Lord Faringdon"
Southern	22	230	44·5	5·24	1390	"Mallard"
Western	22½	205	60·8	3·9	1418	"Seagull"
Eastern	22	215	50·2	4·17	1249	"Lord Faringdon"
Western	25	230	46·0	5·2	1422	"Seagull"
Eastern	25	220	43·4	4·99	1293	"Lord Faringdon"
Southern	25	220	47·0	5·42	1520	"Mallard"
Southern	25	225	53·5	4·97	1590	"Mallard"
Southern	30	230	35·0	7·32	1530	"Mallard"
Eastern	30	220	30·1	6·71	1206	"Lord Faringdon"
Midland	30	200	44·0	5·8	1528	"Lord Faringdon"
Western	35	235	35·8	8·1	1728	"Seagull"
Western	35	200	35·2	7·1	1481	"Seagull"
Midland	35	187	29·5	7·1	1250	"Lord Faringdon"
Midland	40	223	17·0	9·6	975	"Lord Faringdon"
Western	40	200	44·0	6·2	1630	"Seagull"
Western	42	230	24·6	10·0	1457	"Seagull"
Southern	42	200	27·5	9·3	1550	"Seagull"
Western	53	235	20·2	12·6	1522	"Seagull"
Western	53	235	21·0	12·75	1598	"Seagull"

was 30 per cent, but the engine would not take full regulator without slipping. It was the same when starting up the continuous 1 in 190 out of Berwick. Working in 25 per cent cut-off we made no real headway till the crest of the bank was reached, at Burnmouth; speed had actually risen to 36 m.p.h. in 4½ miles of ascent, but it was evident from the way the engine accelerated between bouts of slipping that a far finer performance would have been possible in dry weather.

But on level and slightly favourable stretches of line the engine ran very freely, despite the very heavy train load of 610 tons. Over the 17·8 miles from Christon Bank to Goswick, along the Northumberland coast, speed averaged 71·7 m.p.h. About half this distance is practically level, and on the broken descent to the sea shore at Beal a maximum speed of 83½ m.p.h. was attained. Even including the severe check at Alnmouth

miles between King's Cross and Grantham, with loads of about 500 tons. Had the rails been dry the working of "Kingfisher" in 1945 would have been superlative throughout.

As a reminder of what "A4" engines were required to do as a daily event, skeleton details are given in Table V of some runs made in 1938–39.

Of these runs, No. 2 was the only one not made in ordinary service; this was on a special train on which some extremely fast running was put up north of Hitchin. From the dead start at Stevenage the 47·8 miles to passing slowly through Peterborough were covered in no more than 40 min 38 sec.

Post-war running has been handicapped, as everywhere else, by the time it has taken to bring the permanent way back to anything approaching pre-war standards. But it has been evident that the quality of engine performance is often up to the pre-war standards. A run made on the footplate of

TABLE V—*Details of Runs by "A4" Engines, 1938–39*

	Route	Engine No.	Engine Name	Load, tons gross behind tender	Miles	Actual time, min. sec	Net time, min	Net average speed, m.p.h.
1	York–Grantham	4467	"Wild Swan"	460	82·7	87 41	79½	62·6
2	Stevenage–Grantham	4498	"Sir Nigel Gresley"...	510	76·9	72 23	72½	63·7
3	Grantham–Doncaster	4498	"Sir Nigel Gresley"...	510	50·5	48 47	48½	62·1
4	Darlington–York...	4902	"Seagull"	525	44·1	43 00	43	61·6
5	King's Cross–Grantham	4499	"Pochard"	500	105·5	112 16	111½	56·8
6	Grantham–King's Cross	4900	"Gannet"	515	105·5	102 05	102	62·1
7	King's Cross–Darlington†	2512	"Silver Fox"	265	232·3	195 45	191	73·0
8	King's Cross–Grantham	4464	"Bittern"	510	105·5	110 16	105	60·3
9	Retford–King's Cross	4497	"Golden Plover" ...	575	138·6	150 14	146½	56·6
10	King's Cross–York*	4491	"Empire of India" ...	325	188·2	157 07	156	72·4

* "Coronation" express. † "Silver Jubilee" express.

TABLE VI—*Werrington Junction–Stoke Runs by "A4" Engines*

Year	1937	1938	1938	1939	1948
Engine name	"Sea Eagle"	"Sir Nigel Gresley"	"Pochard"	"Bittern"	"Golden Fleece"
Engine No.	4487	4498	4499	4464	60,030
Load, tons	475	515	500	510	500
Time	Min sec	Min sec	Min sec	Min sec	Min sec
Werrington Junction to Stoke	23 05	21 03	22 95	21 18	20 27
Average speed, m.p.h.	53·6	58·7	56·0	58·0	60·4

the 5.30 p.m. Newcastle express from King's Cross to Grantham in the early summer of 1948 showed that in the most essential facet of train running—ability to develop and sustain a high power output on long adverse gradients—the "A4" engines were still very much masters of their work. It so happens that in pre-war days most of my northbound travelling was on the high-speed streamlined trains, on which very good time was kept, and in turning up heavy load runs for comparison I have only four with more than 470 tons behind the tender. Two of these in particular were very good, but the striking point emerges that my first post-war run with an "A4" northward from King's Cross gave a faster time over the long adverse section from Peterborough to Stoke signalbox than on any of my pre-war runs. The speed through Peterborough was slower than usual, and the comparative times over the 20·6 miles from Werrington Junction to the summit revealed a still greater advantage in favour of the post-war run. These times are set out in Table VI.

What the performance of No. 60,030 involved can be studied in greater detail from the diagram Fig. 7, which shows the gradients, speeds and the engine working. It will be seen that the 4½-mile stretch of 1 in 200 gradient past Little Bytham was cleared without speed falling below 56 m.p.h., and the final stage of the ascent included a minimum speed of 54 m.p.h

TABLE VII—*King's Cross–Edinburgh "Non-Stop" Run*

Engine	60,029, "Woodcock"
Load, gross tons behind tender...	465 tons
Length of trip	392·7 miles
Booked time	440 min
Actual time	431½ min
Time lost by signal and permanent way delays	29½ min
Total net time	402 min
Net average speed	59·0 m.p.h.
Departure from London	13 min late
Arrival in Edinburgh...	4½ min late
Actual time Grantham to Edinburgh	299½ min
Distance, Grantham to Edinburgh	287·2 miles
Average speed	57·5 m.p.h.
Approximate coal consumption, London to Edinburgh	8½ tons
Coal per train mile	47 lb (approx.)

In the working of the summer non-stop runs between King's Cross and Edinburgh picked engines are, of course, used; but even with this reservation the general level of performance during 1951 was high, and on more than one occasion considerable amounts of lost time were regained. Details of a run made in August, 1951, are given in Table VII.

The major part of the delay on this run arose from the late start from King's Cross, and from a signal stop at Corby. In consequence, Grantham was passed 29 min late. The recovery of 25 min clear between Grantham and Edinburgh was made despite a further loss of 6½ min running time through permanent way slacks at Bridge Junction, Doncaster and at Acklington (Northumberland). The engine was in very good mechanical condition and ran freely. Some typical examples of her performance are again given in Table VIII.

The downhill speed at Innerwick was a fine example of free running. The summit point at Grantshouse was passed at 45 m.p.h., and the regulator was closed entirely for the descent of Cocksburnpath bank. In 4 miles of 1 in 96 speed had risen to 74 m.p.h., and it increased further to 77 m.p.h. on 2 further miles descending at 1 in 210.

TABLE VIII—*King's Cross–Edinburgh Run, 1951*

Locality	Gradient 1 in rising or falling	Speed, m.p.h.	Steam chest pressure, lb/sq in	Cut-off, per cent
Tempsford ...	Level	72	165	15
Templehirst ...	Level	75	190	15
Thirsk	Level	69½	225	13
Bradbury ...	Level	63½	200	10
Little Mill ...	1 in 170 R.	50	180	20
Innerwick ...	1 in 210 F.	77	Nil	Coasting

With many of these engines the standard of maintenance is now very good. I had occasion during 1951 to ride with one member of the class which had run approximately 85,000 miles since last general overhaul. The valve setting was accurate, the three-cylinder beat even and true, and there was a notable absence of knock and play in the running gear and the axleboxes. While few could deny that in pre-war years the Gresley "Pacifics" of all classes earned great distinction by their reliability in operating some of the fastest and heaviest passenger train services ever run in Great Britain, the performance of these engines to-day, while less spectacular, shows no deterioration in the essential factor of work done per unit of coal fired, and the thirty-five streamlined engines of the "A4" class can still be regarded as second to none among the express passenger locomotives of various regions now known collectively on British Railways as class "8P."

Human Relations in Industrial Operational Research

A. W. SWAN, B.A.Sc., A.M.I.Mech.E.

After operational research is defined as "The investigation of problems which affect management, using whatever scientific methods are appropriate, and resulting in recommendations which lead to executive action," the method of inauguration of an operational research department and its place in an organisation are discussed. Relationships with higher management and with other departments are then considered, with a section on the planning of the work. Emphasis is placed on the service character of an operational research department, and on the importance of individual and group discussions in carrying out its programme. The concluding section deals with human relations within an operational research department, with a discussion of differences in method and the factors which make for contented and enthusiastic work.

THE following article, which is based on several years' practical experience, has been written mainly for senior executives who are contemplating the establishment of an operational research department, and for engineers and others who are attracted to this work. It is hoped that the views expressed below may prove of assistance in making decisions on the position such a department should fill in an organisation, the method of running it, and, not the least important, the kind of person most suitable to work in it.

For the purposes of this paper, industrial operational research is defined as "the investigation of problems which affect management, using whatever scientific methods are appropriate, and resulting in recommendations which lead to executive action." Problems may have to do with processes, methods of organisation, costs, labour turnover, &c. Available scientific methods may include time and motion study, statistical and other mathematical techniques, &c. By this definition operational research leads to executive action, but is not responsible for putting that action into effect.

Method of Inauguration

The method of inauguration and the integration of the operational research department with an existing organisation will largely determine its success or failure.

Operational research may infiltrate from below, through the interest of inspectors, laboratory workers, &c., who convert their chiefs, who, in turn, eventually "sell" operational research to the top management. Such an introduction can never be more than partially successful, since the influence of the prime movers is necessarily limited to the department or departments in which they work, and the spread of interest, particularly in a complex organisation, is difficult and slow.

The opposite method, to start at the top, has many advantages. In the first place, it is very helpful to the operational research department to know that its work is in line

with the general policy of the company in which it is placed, and that it can count on top management support when necessary. Human nature being what it is, the operational research department is definitely helped when the word has gone around that top management thinks it is a "good thing." Another advantage is that if the initial planning is carefully done, the operational research department will be kept continuously in touch with main policy and the problems which beset top management. When operational research work starts from above rather than from below, it should be able to touch every department and every form of activity.

Convincing Management that Operational Research is Worth While

How do we set about convincing top management that operational research will be worth while? We have first of all to consider how the working of an industrial concern looks to the persons responsible for its management. What are their problems? They are interested in such matters as reducing production costs and increasing output, securing the most effective use of the existing labour and machinery, and reducing wastage at all stages of production. The first stage is to show that operational research sets out to solve these and similar problems. Theoretical arguments are not sufficient, and concrete examples of the successful application of operational research are desirable. There is a growing literature on this subject and suitable examples may be quoted.

The prospective employers of operational research will also wish to understand in a general way the methods by which this new approach intends to obtain the answers they require. They may be sceptical as to the efficacy of a new "magic" to problems, some of which may be of long standing. The protagonist of operational research will show that a high proportion of the problems with which executives are concerned reduce to problems involving numbers: has the introduction of a new process increased output, or has it done so at the expense of increasing the level of defectives or waste? Is a new deployment of men and machines the best possible? In this connection modern statistics is an important tool in the kit of the operational research worker.

Present-day statistics is essentially a science whereby a small group of measurements, which may be of physical dimensions, costs, operation times, &c., is taken as a sample from a possible total of such measurements, known as the "population," and the properties of the population are estimated from the sample. The statistical quality control chart and statistical sampling of materials and components are efficient yet economical substitutes for 100 per cent inspection; statistical significance tests tell us how few results we need to give valid comparisons from plant to plant and department to department; the statistically planned experiment wrings the maximum of information from the minimum of data, and so on. The main emphasis is thus on economy.

The Place of Operational Research in an Organisation

The operational research department must be made an integral part of an existing part of an organisation, its chief reporting to the works, production or research manager, or in a large organisation to an executive director. The advantages of such an arrangement are many. In the first place, the operational research department does not have to seek its introductions to heads of departments, being assisted in this, as in other respects, by the senior executive to whom it reports. A more important point is that the department will be made part of the ordinary managing machinery, taking part in standing and special committees, and therefore being given a regular and simple method of being kept in touch with all the regular activities of the company at executive level. If the operational research department is made free-lance, reporting to the chairman or managing director somewhat as a "personal assistant," there is a danger that it will be the subject of suspicion from all other existing production, sales, &c., departments, a suspicion which would not be justified, but which it may be necessary to overcome.

Whether the operational research department is placed under the works manager, research manager, or an executive director, depends on circumstances. Each of these arrangements has been successful. There has been a tendency to place operational work under research, but the arguments for this are no better than they are for placing it under production. The successful operational research department will be on loan to every department.

One of the major reasons for the success of operational research during the war years was that the scientists engaged on the work had the right of access to and discussion with executive heads of any rank, and the same right of access and discussion not only for the head of an operational research department, but for his senior assistants, is just as necessary in industrial operational research. The matter of status tends to be shelved during preliminary discussions, but status, in the sense described, is of prime importance. The snob value of status, though regrettable, is usually a factor which must be considered by a management which wishes an operational research department to succeed.

Relationship with Higher Management

The relationship of an operational research department with the executive to whom it reports is worthy of careful thought. An operational research department is, under present conditions, a new venture. It uses methods which are not ordinary run-of-the-mill to the production executive and rather apart from the usual line of thinking for the research manager. The senior executive has faith in the possibilities, or the operational research department would not be started. He must continue to have faith. He must also be prepared to allow a reasonable time before concrete results are demanded, as would be done in the case of any process research project. Since the techniques are new to him, he will have to allow a fair amount of latitude in the detailed running of the department while maintaining control over general policy. During the war high ranking officers in the armed Services were on excellent terms with the operational research workers, although the latter were men of different background and outlook. The executive may have come up through the school of experience, while the operational research worker has had training which has been mainly theoretical. If this is the case, differences in outlook exist only to be removed.

The senior executive will be much happier and be able to help the operational research department much more effectively if he understands the basic principles on which it works, and the head of the operational research department therefore owes it to his chief to explain the techniques used, preferably in industrial terms.

The main responsibility of the head of the operational research department is, however, to justify the faith placed in him. He must produce results that are useful to the organisation either (1) in saving money, or (2) in simplifying work for higher management. One of the fields for operational research which has so far been little explored is the cutting down of information to management to essentials; most executives are supplied with far too much information. This service could not readily be assessed in cash value, but would be none the less real.

The busy senior industrial executive rightly insists on guiding the main policies of all who come under him, but usually prefers to have departmental heads who keep him abreast of all main developments, but do not worry him about detail. It is therefore sensible for the head of the operational research department to keep his chief informed of the current position by interim progress reports and by informal conversation as and when required. The emphasis should be on brevity.

Determining the Programme

The operational research department must have a programme of work. This programme can be settled by the department or from outside the department. At first sight it might seem that the correct method is for the operational research department to analyse the general position, determine where improvements can be effected, and go to work. Such a policy would, however, be the height of folly, leading to suspicion and jealousy and stifling co-operation, the lifeblood of operational research, at the outset. The sensible policy is for the operational research staff first to get a basic understanding of the organisation and a personal acquaintance with the men concerned in it.

Once acquaintance has been made, the operational research worker will explain to each individual in turn the service that his particular techniques can give. He will make it clear from the beginning that service is the key word, that the operational research department, far from endeavouring either to cause trouble to existing departments or to steal their credit, wishes to assist and to build up the reputations of its colleagues. Reports will be issued jointly with departments which co-operate, and full credit will be given for all information and help supplied.

The quality of tact is sometimes mentioned as desirable in an operational research worker. A simpler and more accurate term is "sympathy." If the operational research worker is sympathetic with the point of view of the departmental executive with whom he has discussions, obstruction will be rare. Sympathy must be coupled with respect. The operational research worker must realise that he is dealing with men who have specialised knowledge just as he has, and who are at least as experienced as he is in industrial tactics.

Individual explanations, as described above, always produce requests for assistance, and from these requests the operational research department, with the guidance of the senior executive to whom it reports, will select a programme. It may be objected that this method may give a programme which is badly balanced and incomplete, omitting essential jobs which the operational research department might have suggested. The only answer to this point is that the writer has never yet had such an experience.

It would be naïve, however, not to admit that as time goes on and the operational research department gains knowledge of conditions and problems, it will have suggestions to make. Requests from executives of other departments may have a remarkable resemblance to these suggestions.

Discussions with Other Departments

Discussion is a vital part of operational research. Once a job has been undertaken the operational research department must keep in close and constant touch with those from whom the request came, in the collection of data and the framing of experiments, in the discussion of results, and in the issue of the final report. One of the outstanding advantages of this method is that the operational research department can remain small and therefore economical, since it can, at will, tap an enormous fund of specialised knowledge. Furthermore, operational research workers need not spend undue effort in trying to learn the complete technology of varied kinds of product, since the appropriate specialised knowledge is always available. Consider, for instance, a company which manufactures turbo-electrical plant, small and large motors, transformers, &c. If it sets a problem relating, say, to turbine blade clearances, the operational research worker will have men skilled in the appropriate branches of knowledge at his elbow, willing and anxious to assist.

Discussions with individuals should be as informal as possible. There are many who find that their minds work more freely and to better advantage after a preliminary few minutes on non-business subjects, and the operational research worker who begins a discussion with the head of a works office with an interchange of ideas on, say, choral singing in Cumberland, if that is a congenial subject, is not wasting his time.

Individual discussions should be followed by group discussions which follow the work as it proceeds. These may usefully cut across normal departmental lines and thereby produce new and unexpected material. By virtue of the informal character of these talks, and because they often include elements not found in normal standing committees, it frequently happens that technicians and others bring forward suggestions of their own which have lain semi-dormant possibly for a long time, and these suggestions provide useful ground for action. It also happens, on occasion, that troubles which have come to be accepted as more or less inevitable, although the remedy was well known, are so brightly lit that action is at last taken.

It is always advisable for the operational research worker to prepare an agenda, beforehand if possible, and also to have suggestions for action.

One of the benefits which accrue from taking part in group discussions is that the operational research worker is trained in committee work, a subject not commonly included in his earlier studies. He learns as a member, secretary or chairman of a group, to help discussion to be constructive, to the point, and free from repetition, without hurting feelings.

The operational research department will inevitably have its disagreements with the technicians. When these occur, the rule should be that they must be dealt with by personal discussion rather than by correspondence. Few disagreements will survive a man-to-man discussion, and if they remain as disagreements there will be no hard feelings. Correspondence, however, even between two genial and upright people, can lead to bitterness and serious trouble. The writer has seen bitterness resulting from correspondence removed by a morning of personal discussion. This discussion grew more and more friendly; compromise suggestions were agreed to and the quarrel was over. On another occasion the writer had to issue a report which ran contrary to the wishes of a certain departmental manager. The manager cursed him roundly, vigorously and jocularly, and they remained friends. When a disagreement proves difficult to resolve, the operational research worker may recollect the Oriental and perhaps universal principle that it is necessary in a quarrel to leave one's opponent a way out so that he may withdraw from an awkward position without loss of "face."

Just as motion study cuts out inefficient actions in mechanical processes, so what may be called psychological motion study avoids inefficient actions in discussion. Mental resistance is a form of internal friction which reduces efficiency. It is therefore a prime object in argument to see that resistance is kept to a minimum. Compulsion, obstructive criticism and reproaches for past actions all build up resistance and are avoided as inefficient methods.

Reports

Reports issued by the operational research department require very careful thought. They must always be read by the production or other departmental heads affected before issue. They may or may not agree with the findings, but they are in the picture. Reports must be written in a form useful to the recipient. He has asked certain questions; he is interested both in the actual results and in the actions suggested. The report, therefore, must start by stating the problem, setting out the answers, and giving recommendations for future executive action. The experimental and analytical methods should then be given as being of general interest, but mathematical and statistical techniques are interesting only to the operational research worker and his brethren, and should be included only as an appendix. The language used should be straightforward, and such technical language as is used should be that of the man to whom the report is addressed, not that of the man who writes the report. Thus, a report on viscose rayon manufacture might reasonably use the term "ballfall" when discussing viscosity as this would be familiar to anyone on the technical side of the industry, but it should not use such expressions as "confidence limits," which would be familiar only to statisticians.

Some years ago a certain managing director said to the writer, "I have people who will read your reports in detail, but if you wish me to see anything in any of them put it on page 1; if it is on page 2 I shall not see it."

Relationships Within the Department

The head of an operational research department and his senior staff will have similar backgrounds to the extent that each will have had specialised training in technical subjects such as engineering, physics, mathematics, &c., and will be interested in working mainly among fellow human beings rather than from books or among laboratory instruments.

Habits of thinking differ, however, among equally able people and it is the rather difficult task of each member of an operational research group to allow for that fact. The mathematician, for instance, may prefer to solve a problem by considering it in general symbolic terms, while the engineer may say, "Let us take a specific case and work through it in detail." They arrive at the same answer by different routes. An important corollary of this fact is that in operational research work there are often several methods of solving a problem, all of which are right.

There are variations in regard to the importance of detail. Killeffer, in *The Genius of Industrial Research*, points out that sudden inspiration is rare and that the necessary preliminary to all research work is the collection and assimilation of as much relevant data as possible. The writer once had a brilliant assistant who waited for inspirations and rather irritatingly usually had them while the writer was still amassing information. Another assistant had a passion for the collection of the most detailed information. Both were right, each using the method of thinking to which he had trained himself.

To say of a judgment that it is "intuitive" is not necessarily a criticism. Intuition can be defined as the subconscious use of stored knowledge, and the intuitive judgment on a statistical matter of an operational research worker would be very different from that of a factory operative. Conscious and subconscious judgments are affected by the disciplines to which one has been subjected. The subconscious mind plays an important part in all analytical thinking, and due allowance should be made for the subconscious steps in working out the solution to a problem. As one learns a subject, knowledge tends to pass to the "of course" stage. One tends to find oneself surprised at those who do not have that particular item of information, and it is only when one is called on to justify a specific point that one may find that the original train of reasoning was quite intricate and is difficult to recapture in detail. The writer once had an example of this fact when he designed a special slide rule for works use. As he had had to design slide rules before, it all seemed very simple and obvious, but when the job was completed it proved to be quite a lengthy proceeding to explain why, for example, multiplication was by reversed log. scales, why there was one sliding scale and a cursor instead of two sliding scales and no cursor, &c.

A difficult problem of internal management in an operational research department, which involves the study of human relations by the head and staff, is that of direction of policy. The head of the department has to shoulder the responsibility of planning and maintaining a policy, of allocating work, and of seeing it through. If anything goes wrong he must bear the brunt. On the other hand, the assistants are capable people and they are, usually by the very nature of their training, individualists with strong views on most subjects. If disagreement develops between chief and assistant, as it may even between good friends, the only decision possible if the department is to continue is that the chief must hold to his decision, and the assistant, mainly perhaps because he will some day be in charge of a department and have the same problem, must defer.

The factors which lie behind contented and enthusiastic work have been examined by many able psychologists. The scientific worker, like anyone else, is interested in present salary and future prospects, and the wise management recognises this fact, not only in regard to salary scales within the operational research department, but in making it part of the general scheme for the selection of higher executives throughout the organisation. Operational research is an excellent training in the general principles of management, and the operational research worker has unusual opportunities for getting

to know the policies, problems, and personalities of the company for which he works. The writer can call to mind cases in recent years, where operational research workers have gone on to sales and production executive positions with complete success.

Satisfaction with material aspects is incomplete. The operational research worker must feel that he has full opportunities to expand his knowledge. Encouragement and opportunity should be given to attend operational research meetings and lectures, not only for the sake of the actual content of the papers, but to meet others working in the same field, to exchange views and discuss problems. One of the greatest personal assets in business is to know where to get information outside one's own organisation. Common sense will be used in the selection of the number and type of meetings attended.

The operational research worker, however junior, wishes to make a name for himself, and this is a reasonable ambition. Ways and means must vary according to the organisation, but, taking into account the company's regulations regarding the circulation of confidential information, an effort must be made to allow the presentation of papers. These papers should be given both to the technical societies in which the organisation is interested — engineering, textile, chemical, &c.—and to those societies which deal with the techniques of operational research. This means, among other things, that the operational research worker must learn how to give public lectures and take part in discussion. He thus learns the method which best suits him—reading word for word, notes, or impromptu learned the night before—and, in particular, he learns how to take forty-three minutes if allowed forty-five minutes. H. E. Dance, of the Ministry of Education, once said that an audience will forgive a lecturer almost anything when they are sure that he is trying to help them. That is not a bad thought for operational research in general.

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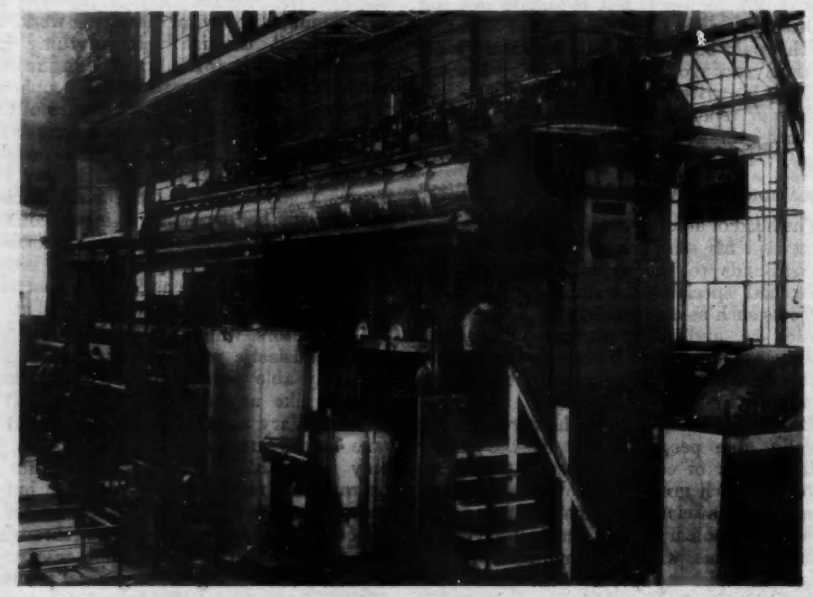
Diesel Engine for Geared Drive

The increasing employment in ships of multiple diesel engines driving the propeller shaft through hydraulic or electro-magnetic couplings and reduction gearing, has led Sulzer Brothers, Ltd., to develop an engine specially designed for this form of machinery installation. The prototype engine which is now undergoing tests is briefly described and detail changes in design are commented upon.

SINCE it first made its appearance as a prime-mover for ship propulsion, the diesel engine has been improved constantly to increase its overall efficiency. There have been two- and four-stroke engines, fuel injection systems have been varied, improved scavenging systems have been adopted and opposed piston engines have been developed, while supercharging has served to increase output. The introduction of welding also has had an effect in that composite construction has superseded cast iron for many applications, with a resulting saving in weight, thus improving the power/weight ratio, and also reducing the overall length of the engine. In recent years economic pressure to reduce fuel cost has seen the success of the experimental work designed to allow the diesel engine to burn boiler fuel.

Present-day trends are towards larger and faster ships, calling for increased power, which has to be transmitted to a single shaft. In many instances, the steam turbine has been adopted, but another solution of the problem has been the combination of two or four diesel engines, arranged to drive the propeller shaft through hydraulic or electro-magnetic couplings and reduction gearing.

Many ships have been equipped with this arrangement of propulsion machinery, including the 9500 tons deadweight cargo liner "Cornwall" which was built and engined by Alexander Stephen and Sons, Ltd., for the Federal Steam Navigation Company Ltd. The machinery installation consists of two Stephen-Sulzer two-stroke engines of crosshead design, each having eight cylinders of 580mm bore by 840mm stroke and developing 4000 s.h.p. at 225 r.p.m., and delivering a total of 7600 s.h.p. to the propeller shaft through hydraulic couplings and double helical single reduction gearing.



ENGINE ON TEST BED

For the next series of geared drive ships, Sulzer Brothers, Ltd., of Winterthur, Switzerland, has designed and built a new engine, and at the company's invitation, we recently, paid a visit to the works at Winterthur to inspect one of the new range of engines at present undergoing test bed trials. The engine, which is of basically the same design as the existing series, has been designed more particularly for geared drive propulsion, and incorporates many detail changes and some of a more major character, dictated by conditions obtaining at the works of the company's licensees.

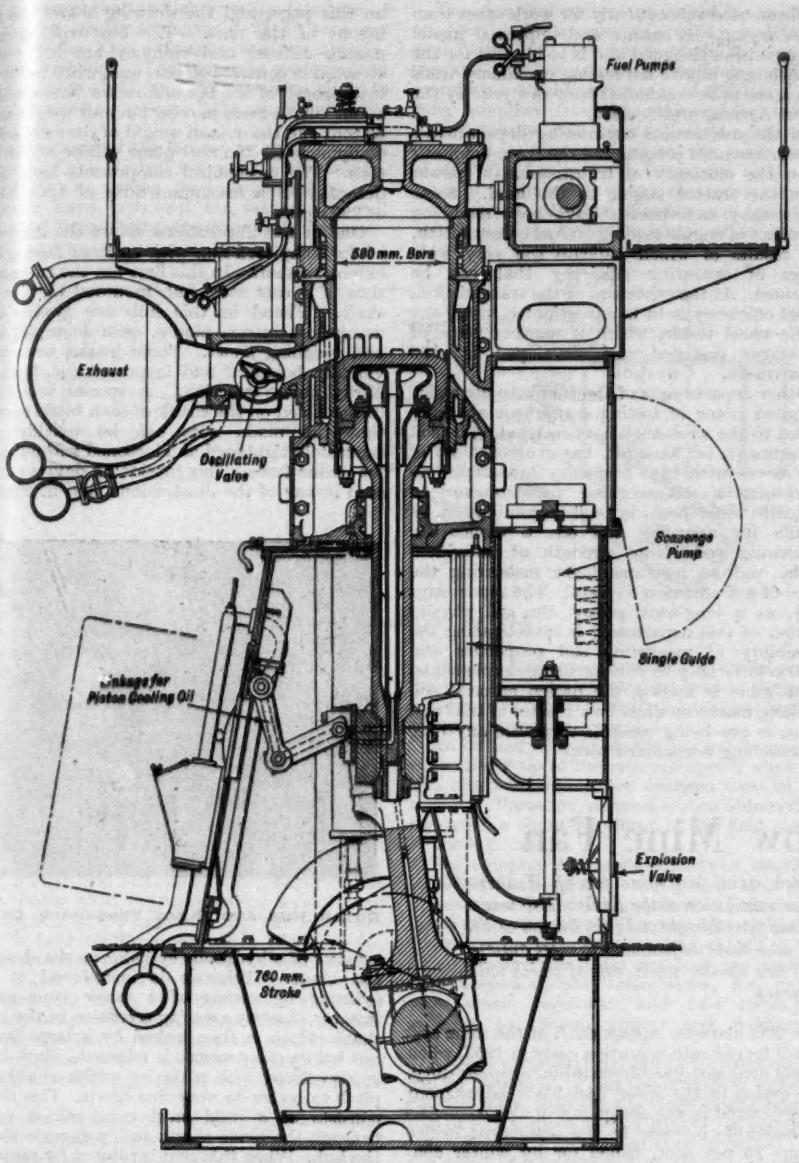
The prototype engine illustrated herewith has ten cylinders and is one of a pair to be installed in the cargo liner "Middlesex," which is under construction for the Federal Steam Navigation Company, Ltd., at the yard of Alexander Stephen and Sons, Ltd., where the other engine is being built. The overall length is 12·175m and the height 5·505m while the height above base-plate for withdrawing the cylinder is 6·280m.

Problems of erection, of adjustment and design modification are being solved on the engine building in Switzerland. In addition to the engine already mentioned, John Brown and Co., Ltd., has under construction two ten-cylinder and four twelve-cylinder engines for the New Zealand Company, Ltd., and two seven-cylinder engines are being built in Holland for Norwegian ship owners.

This new engine, shown in our sectional drawing, is directly reversible and of two-stroke, single-acting crosshead design, having a cylinder diameter of 580mm and a stroke of 760mm, which is slightly shorter than the earlier engines. Each cylinder has a moderate continuous rating of 450 b.h.p. at 225 r.p.m., at a b.m.e.p. of 4·95 kg per square centimetre, and at full load each cylinder develops 500 b.h.p. at 230 r.p.m., while at 250 r.p.m. the overload rating is 615 b.h.p., with a b.m.e.p. of 5·5 kg per square centimetre. The first pair of ten-cylinder engines will have a total continuous output, at sea, of 9000 b.h.p. at 225 r.p.m. when driving the propeller shaft at 100 r.p.m. through B.T.H. electro-magnetic couplings, and gearing supplied by the Power Plant Company, Ltd. At three-quarters load the engine turns at about 205 r.p.m., and when reducing speed the engine has been notched back to 40 r.p.m. and has continued to turn over steadily.

Fabrication by welding has been extensively employed in the design so that from the cylinders downwards the engine is built from welded plate. This system of construction does not represent any radical departure from the company's practice since it has been building double-acting engines with welded frames and bed-plates for over twenty years. British builders of the engine prefer welded construction because it is cheaper, and because iron castings are difficult to obtain. In Switzerland, the position is reversed, so that the engine is available as a cast iron or welded design. However, the welded engine does represent a 12 to 15 per cent reduction in weight over the cast iron design, and the weight per brake horsepower for the bare engine is estimated at approximately 40 kg, and at 50 kg per brake horsepower for installation complete with couplings, gearing and essential auxiliaries. It is recognised that the complete stress relief annealing of large-size components presents some difficulties, and to avoid imposing tensile stress on the welds, long steel tie-bolts extending from cylinder to bed-plate have been incorporated.

In preparing the design, it was decided to produce an engine having the same long life and operating reliability as in a direct propeller drive, so the crosshead was retained. The additional height entailed was compensated for by adopting a short-skirt piston and by cutting down the space required for the removal of pistons and liners. The crosshead design, while relieving the piston of lateral pressure, makes it easier to separate the combustion chambers from the crankcase. This has been



CROSS-SECTION OF TEN-CYLINDER ENGINE

done in this engine to avoid contamination of the lubricating oil in the crankcase which the piston rods enter through a stuffing box.

The adoption of a short-skirt piston has meant a departure from well-established practice for controlling the exhaust and scavenge ports and for inspection and observation. Other means have been chosen to close the ports which are uncovered by the piston at top dead centre, and since the crankcase is sealed off from the combustion chambers, it has been possible to incorporate an oscillating exhaust flap valve. This form of valve has been a matter of study and experiment over a number of years, and its adoption makes it possible to dispense with the upper row of scavenge ports adopted in the company's other marine engines. By closing the exhaust valves at the end of the scavenging stroke, when the scavenge ports are uncovered, after-charging is achieved, the air in the cylinder being at the same pressure as the air in the scavenge belt. The valves are actuated by a specially-designed elastic drive, and since they are located on the upper part of the engine, the control gear has been combined with that of the fuel pumps in the form of a single camshaft driven by a chain from the crankshaft.

The individual lateral pattern scavenge pumps discharge into a common receiver and instead of being operated by rocking levers from the crossheads the pistons are rigidly connected to the latter by means of a bracket arm. With this arrangement, the scavenge pump piston has the same stroke as the engine, and the bushing through which the piston rod passes is specially designed to maintain alignment and to allow for wear of the crosshead guide. There is only one guide; this has a double slideway and is attached to the cylinder block of the scavenge pumps, which is built as a separate unit and mounted later on the engine frames. This arrangement simplifies machining problems and expedites final assembly. The air enters each scavenge pump through a group of seven venturi-shaped slots and the upper part of the cylinder is fitted with two relief valves at each end, set at 7 lb per square inch. In the crankcase covers explosion doors are fitted; these are circular and act as valves, a centrally-placed return spring being fitted inside the cover.

The engine is intended to burn heavy fuel and test runs have been carried out already on 3000 seconds fuel; it is expected that the engine will operate successfully on high viscosity fuel up to 6000 seconds Redwood I at 100 deg. Fah. The oil fuel pumps, which are tested to 1000 atmospheres, are mounted in pairs on the top of the engine, so that the pipe to the centrally-placed injection valve is as short as possible to obviate any drop in temperature of the fuel. The pumps are of double-valve controlled pattern, and the main fuel line is lagged and heated so that the temperature of the heavy fuel is maintained. The cylinders and fuel injection valve are water-cooled, while the pistons, which have a cast iron skirt and forged steel head, are oil-cooled. White metal bearings have been adopted, and these, together with other working parts, are force-lubricated, the oil being circulated by an electrically-driven lubricating oil pump, which can be engine-driven if required. Engine controls are arranged at the forward end of the engine, and are designed so that for a geared drive installation one engine acts as the master.

Another engine is also under development at Winterthur; this is intended for direct-drive propulsion. It is larger than the geared-drive unit, having cylinders of 760mm bore by 1550mm stroke, which have a continuous rating of 900 b.h.p. at 115 r.p.m., with a b.m.e.p. of 5 kg per square centimetre. With the b.m.e.p. increased to 5·5 kg per square centimetre, and the speed maintained at 115 r.p.m., the power produced per cylinder is 1000 b.h.p., and with the revolutions per minute raised to 120, the power is increased to 1100 b.h.p.

The National Institute of Agricultural Engineering

THIS week there have been some "open days" at the National Institute of Agricultural Engineering, Wrest Park, Silsoe, Bedfordshire, and many visitors have had an opportunity to see something of the research and development and testing work that is now being undertaken there. The Institute was moved to its present quarters about five years ago, Wrest Park having been chosen as the Institute's permanent home because of its proximity to a variety of soils and to other research stations, and also because it is situated in the middle of an important agricultural and horticultural area. At the same time, the Scottish Machinery Testing Station was set up at Howden, Midlothian, as part of the Institute's establishment.

In September, 1949, the control of the National Institute of Agricultural Engineering passed from the Ministry of Agriculture to the Agricultural Research Council, the administration being undertaken by the British Society for Research in Agricultural Engineering. The Earl of Radnor is chairman of the governing body of the Institute at Wrest Park, and Mr. John Mackie is chairman of the Scottish committee of the governing body, which is responsible for the work of the Scottish Machinery Testing Station. Mr. W. H. Cashmore is the director of the Institute, and Mr. W. J. West is the director of the Scottish station.

This week, there has been issued a report which surveys the work of the Institute during its first two years under the control of the Agricultural Research Council, i.e., October 1, 1949, to September 30, 1951. Its several chapters deal with the principal activities of the Institute's departments, which are concerned with agricultural testing, field investigation, grain drying and storage, horticultural engineering, instrumentation, mechanical engineering, and soil. A separate chapter is devoted to the work of the Scottish Machinery Testing Station, and the report also includes references to the work of the Institute's information unit and to the test reports which are available on a variety of tractors and other agricultural machinery. In the two-year period reviewed in the report the agricultural testing department has carried out about 100 tests on machines which, the director says, were "very varied." Before a test is carried out a scheme is drawn up and discussed with the manufacturer. The specification is carefully checked and the actual test includes at least fifty hours' work in the field, during which time as many measurements as are thought to be necessary are taken. The report made by the Institute includes the results of the various tests, the general conclusions, and general recommendations for improvements in design. A fair proportion of the machines tested are prototypes or early production models, and for that reason, of course, several reports are not published, but are made available only to the manufacturers. The testing scheme is operated primarily for

machinery manufacturers, though the published reports are also useful to farmers. The assistance to farmers may be of an indirect nature, because many recently introduced versions of implements owe some improvement to the N.I.A.E. test, while, in some cases, the test results in an unsatisfactory machine either being with-drawn or redesigned.

The work of the mechanical engineering department at Wrest Park is particularly interesting. The department covers testing, research and development, and includes the drawing-office and engineering workshop which serve the whole of the Institute. According to the report, testing activities in this department are confined mainly to tractors, grain and grass driers, and other ancillary equipment, and in each case a N.I.A.E. standard test has now been established. In June, 1951, a British Standard test for tractors was published, which is comparable with the Nebraska test and meets the requirements of the British tractor industry. Research is now proceeding in the department with the object of improving test technique. An article describing some of the apparatus, which has been designed at the Institute, for the testing of agricultural machinery was contributed to THE ENGINEER by Mr. H. J. Hamblin, head of the mechanical engineering department, and was published in our issue of August 3rd, 1951. One such item of equipment is a mobile weighbridge, which can be folded up to form a trailer for transport. The need for it arose in connection with the testing of grass driers, it being essential to weigh accurately the trailers bringing grass from the field to the drier. The trailer-weighbridge was introduced two years or so ago and has been used subsequently for work other than grass drying. A second and improved model has now been designed and is to be used for the forthcoming potato harvesting machinery trials which are to be conducted later this year by the Royal Agricultural Society.

In the mechanical engineering department's tractor research programme the main emphasis is on the efficiency of transmission of power from the tractor engine to the land. Some preliminary experiments have been made on the effect of engine loading on fuel consumption, the results of which indicate the very wide range of operating efficiency that can be obtained. At the other end of the transmission, wheel efficiency is to be investigated, using the single-wheel tester, which is another piece of apparatus designed and developed by the department.

Other departments of the Institute have also designed items of testing equipment specially suited to the work they have in hand. The soil department, for example, has evolved a set of soil sieves with high-frequency low-amplitude vibration, a self-recording penetrometer to indicate differences in soil consolidation, a needle for sampling soil air, a device for measuring soil shear strength of individual clods, and an instrument for measuring the force of soil adhesion to metal. The report says that, as a long-term policy, the soil physics section of this department is investigating the possibility of measuring soil properties and their relationship to various tillage implements. Until more is known, the design of most soil working machines must be a matter of trial and error, it not being possible to devise anything approaching a standard test.

A Large Axial-Flow Mine Fan

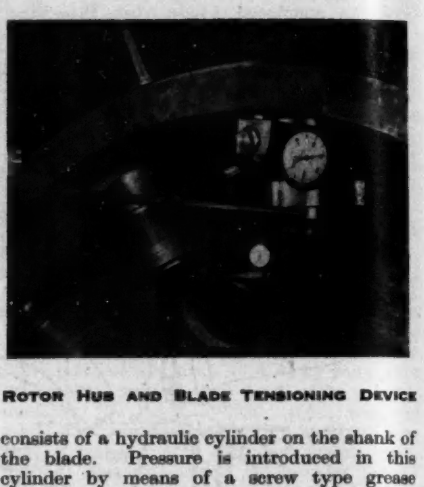
A 209in diameter single-stage, adjustable pitch, axial flow mine fan of Walker-Macard design has been built in this country for ventilation at the Broken Hill mine of the Zinc Corporation, Ltd., in Australia. This fan, thought to be the largest of its kind in the world, incorporates means of speed and blade adjustment to meet anticipated altered mine conditions. It is the first of two similar units, one of which will be used as a standby in the event of an emergency.

A SINGLE-STAGE axial-flow mine fan, recently completed at the works of Walker Bros. (Wigan), Ltd., for installation in Australia at the Broken Hill mine of the Zinc Corporation, Ltd., is stated to be the largest unit of its kind yet constructed. This fan is 209in diameter and it has been designed for an initial duty of 720,000 cubic feet per minute at 1·75in S.W.G. and a final duty of 900,000 cubic feet per minute at 3·74in S.W.G. It will be driven by an 850 h.p. motor having a range of speed varying between 296 r.p.m. and 240 r.p.m.

The new fan, which is the first of two generally similar units, will be installed in a new 20ft diameter upcast shaft at the mine and it will be put into operation early in 1953, when it will deal with the above initial summer duty. By means of the speed and blade adjustment incorporated in the design it will also cover the considerable increase in the equivalent orifice about 25 per cent, called for by winter conditions. The makers state that during the next twenty years it is proposed to make suitable speed and blade adjustments to meet altered mine conditions which have been anticipated by the mining authorities in Australia.

Some photographs of the new fan in course of erection at the maker's works are reproduced on this page, and the drawing shows the site layout of the unit. The fan drift, suction nozzle, diffuser and chimney are being constructed in concrete on site, and, when built, the total length of the fan and motor house will be about 200ft. Each moving fan unit weighs some 40 tons and the overall weight of the mechanical equipment for the new plant will be about 100 tons. The mechanical components have been designed for a maximum duty of 1200 b.h.p. at 296 r.p.m.

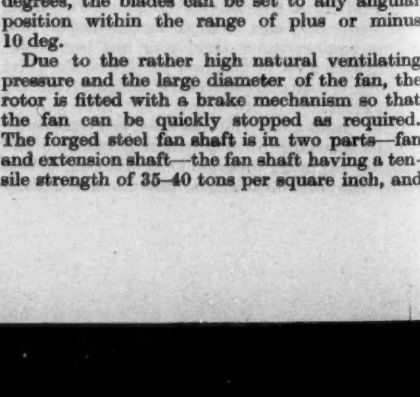
One of the illustrations shows the inlet end of the completed fan, with its front fairing and extension shaft. In this first fan the rotor consists of a cast steel hub mounted on the fan shaft. Fitted in this hub are twelve cast manganese bronze blades, each some 5ft long and weighing 5 cwt. These blades were individually balanced and inspected for flaws by X-ray before erection. A special tensioning device fitted on the shank of each blade ensures that the blade nuts can be quickly and accurately tightened and loosened without need for undue force. This tensioning device can be seen in one of the illustrations, and in effect it



ROTOR HUB AND BLADE TENSIONING DEVICE

consists of a hydraulic cylinder on the shank of the blade. Pressure is introduced in this cylinder by means of a screw type grease injector, thereby creating a tension in the blade shank which is then locked by a large bronze nut before the pressure is released. Each blade is also fitted with a device which enables its pitch to be set to very fine limits. This device consists of a mild steel cam, which passes through the blade shank and engages a slot in the hub. When this cam is rotated by means of a spanner, the blade nut having first been slacked off, the blade slowly revolves about its centre. Then, with reference to a fixed index plate mounted on the hub and marked out in degrees, the blades can be set to any angular position within the range of plus or minus 10 deg.

Due to the rather high natural ventilating pressure and the large diameter of the fan, the rotor is fitted with a brake mechanism so that the fan can be quickly stopped as required. The forged steel fan shaft is in two parts—fan and extension shaft—the fan shaft having a tensile strength of 35–40 tons per square inch, and

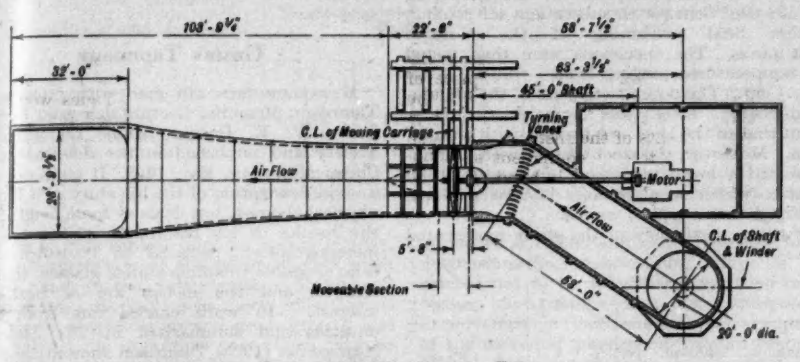


OUTLET END OF FAN

INLET END OF FAN

the extension shaft, which is at the inlet end of the fan, a tensile strength of 28–32 tons per square inch. This extension shaft is approximately 45ft long. The motor is connected to the extension shaft, and the extension shaft to the fan shaft, through "Standage" flexible couplings.

The bearings of the fan are on rigid supports and are of the Michell tapered oil film design. In addition to taking the journal loading, the bearings have provision for taking the end thrust of both shafts, together with the main



SITE ARRANGEMENT OF FAN

and reverse thrust of the fan rotor. Each bearing is supplied with lubricant from a common oil tank in the motor house and the level of oil at each bearing is shown by an adjacent sight gauge on the fan.

The temperature of each bearing is shown constantly on thermometer dials in the motor house. Dual electric contacts fitted to the bearing thermometers serve to switch on a warning light in the motor house should the temperature of any bearing approach danger level, and to trip out the circuit breaker of the main motor when the temperature level of any bearing is near the danger point. The fan brake gear is held off by a solenoid, which is de-energised when the motor circuit breaker opens, thus, if the temperature of any bearing reaches an abnormal level, and the motor circuit is broken, the fan brake is automatically applied to stop the fan in the shortest possible time. An interlock switch is fitted to prevent the driving motor being started with the fan brake on.

The fan casings, consisting of guide vanes, runner ring and centre casing, are built up of steel plates reinforced by rolled steel sections to give strength and rigidity. The casings housing the fan rotor have feet welded on to them, and they are mounted on a carriage. Mild steel guide vanes, pressed to the required curvature, are welded radially to the casings and have their inner facings welded to a support or spacing ring. These guide vanes are arranged in front of the fan blades to give a counter swirl to the axially moving air before it meets the leading edges of the blades, which have an angular velocity, to make the resultant flow of air truly axial. The "Cor-Ten" steel fairings are well reinforced by rolled steel angles and flats and are suitably shaped to produce a streamlined flow of air over the internal parts of the fan.

The carriage on which the fan portion of the unit is mounted runs on wheels which can be swivelled, and it can be lifted by means of hydraulic jacks. Pads and shims are provided to enable the carriage wheels to be lifted clear of the ground when the fan is running, and the carriage is securely bolted to its concrete foundation before the fan is put in service.

The second fan unit under construction is generally similar in design to the first fan unit, except that all casings are constructed of "Cor-Ten" steel and the rotor is fitted with internally operated variable pitch blades. By means of a special toggle mechanism the blades can be all turned simultaneously to any desired position within the range of plus or minus 10 deg. This means of adjustment reduces the time taken to change the pitch of the blades when it becomes necessary to do so owing to mine conditions.

The electrical equipment for the fan has been supplied under a separate contract by Mather and Platt, Ltd. The fan is driven by a special variable-speed equipment comprising a main wound rotor induction motor of 850 b.h.p. output, supplied from the three-phase, 40 c/s, 6900V supply, and an auxiliary d.c. motor of 65 b.h.p. output coupled to the main motor shaft. The d.c. motor is connected to the slip rings of the induction motor through a mercury arc rectifier. By this means, the output from the rotor of the induction motor, when running at reduced speed, is converted into useful power instead of being dissipated as heat in the rotor resistance as occurs with the more usual method of rotor resistance control.

An ordinary liquid starter is used to run the main motor up to the required speed, when the slip ring connections are changed over to the rectifier. Variation in speed is then obtained by means of a shunt regulator in the field circuit of the d.c. motor.

The equipment consists entirely of standard industrial components, no special a.c. commutator machines being required as with similar forms of speed control. The complete equipment comprises a wound rotor induction motor, liquid starter, six-phase mercury arc rectifier with three/six-phase transformer, d.c. motor with shunt regulator, and two triple-pole switches to connect starter and rectifier in circuit.

A speed variation from 240 r.p.m. to 280 r.p.m. can be obtained. When the induction motor is running alone with the slip rings short-circuited the full-load speed is 296 r.p.m. A complete spare induction motor has been provided. In the event of a breakdown on the d.c. motor or rectifier the main motor can run alone at full speed.

A Silent Rotary Swaging Machine

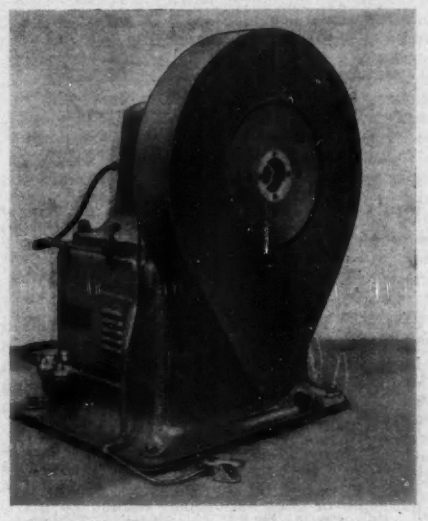
ROTARY swaging machines, introduced by Sir James Farmer Norton and Co., Ltd., of Adelphi Works, Salford, 3, some eighty-five years ago, have long been used, both in this country and abroad by firms manufacturing ferrous and non-ferrous bars, tubes, rod and wire, for prepointing the ends of the bars, &c., prior to drawing to size through a die. As one of the quickest and cheapest methods of making end reductions it is also used extensively for reducing and sizing the ends of pedal cranks and small spindles, swaging of ferrules and shackles on wire rope cables and hawsers, &c.

The range of rotary spindle machines manufactured by the company has now been extended by an additional range of inverted type stationary spindle machines designed to perform heavier duty present-day demands. The photograph we reproduce on this page shows one of the firm's "No. 1. S.I." inverted machines for swaging steel bars up to 1¼in diameter, steel tubes up to 2¼in, non-ferrous bars up to 2in, and non-ferrous tubes up to 3in diameter. This new machine incorporates several interesting points in design to improve the operation and to reduce wear and maintenance costs.

The main improvement is the incorporation of an air-operated silencing device, whereby the dies are positively closed and the hammer blocks relieved from the striking rollers when the machine is running but not actually swaging. When swaging, the dies and hammer blocks are automatically released and no extra force, when feeding the work piece, is required to overcome the relieving mechanism. Wear only takes place when the machine is actually swaging, and there is a considerable reduction in the noise usually associated with swaging machines. Incorporated in the air supply line of the machine is a Norgren "Vitalizer" unit, which, besides providing efficient filtration of the air, also creates an oil fog which ensures adequate lubrication of the die and hammer block guide faces and also of the main roller race carrying the striking rollers. An auxiliary feed from the main air supply is connected to the rear of the hollow spindle, and is operated by a hand controlled valve to give an air blast to the dies for dislodging any particles of swarf, &c., which may adhere to the die faces.

The makers point out that these improvements can be incorporated in their rotary spindle machines and are standard equipment in the fixed spindle inverted machines.

The "No. 1. S.I." machine illustrated is of very robust construction and comprises a box section close-grained cast iron head, which is bored to take the large-diameter shank of the steel spindle. At its front end the spindle is machined and ground after hardening on its outer diameter, front face and the faces of the slots in which the four-piece die and hammer blocks slide. The dies and hammer blocks are themselves of special steel and ground all over to ensure precision fitting. The hammer blocks are fitted with renewable hardened special steel rollers, which make contact with the main striking rollers when transmitting the blows to the dies. A removable hardened steel plate bolted to the front face of the spindle acts as a retaining plate for the hammer blocks, roller race and flywheel. This plate is bored out in the centre for the fittings of a die retaining plate, which can be quickly removed when changing of dies is required. The main roller race consists of twelve hardened and ground striking rollers carried in a phosphor-bronze cage giving free rotation of the rollers. This main roller race also acts as the roller bearing for the main flywheel of cast iron, which is fully machined and balanced all over. Shrunk into the bore of the flywheel is a large steel ring, hardened and ground all over with its bore ground after mounting to ensure precision clearance with the roller race. The drive is transmitted by an endless flat belt to the outside of the flywheel from the pulley on the motor shaft. For controlling the length of swage produced on these machines the hollow spindle is fitted with an adjustable centre tube with a stop end, which ensures that workpieces all have identical lengths of swaged ends.



INVERTED ROTARY SWAGING MACHINE

Metallurgical Topics

Influence of Nitrogen on Low-Temperature Brittleness of Heat-Treated Carbon Steel

MANY investigators have made a study of notch brittleness of mild steels at low temperatures. The effect of oxygen and of nitrogen, of heat-treatment and of grain refinement have been discussed. It is a matter of common knowledge that aluminium or titanium-treated mild steel has a lower transition temperature from tough to brittle fracture than a similar steel not so treated. This may be due to grain refinement, deoxidation or fixation of nitrogen or to some combination of these. Results of several investigations have indicated that oxygen in solution or present as iron or manganese oxide has a detrimental effect on mechanical properties at low temperatures. J. D. Fast found that the energy absorbed by high-purity iron in the notched-bar impact test at room temperature decreased with increase in the amount of oxygen present. Iron containing 0·015 per cent of oxygen had a transition temperature about 50 deg. Cent. higher than that of a similar iron killed with aluminium, titanium or zirconium. Work

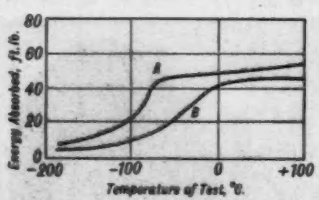


FIG. 1—*Effect of Temperature on the Impact Value of Hardened and Tempered 0·3 Per Cent Carbon Steel Containing 1·6 Per Cent of Manganese, A with, B without, Aluminium Addition (Geil, Carwile and Digges)*

at the N.P.L. has shown that in normalised high-purity iron the transition temperature in impact tests begins to rise steeply if the oxygen content increases above 0·003 per cent, owing to intergranular brittleness, which results in a partially intergranular fracture.

Deoxidation with aluminium, titanium, &c., generally results in improved low-temperature properties; but, as indicated above, the influence of these additions cannot be attributed solely to the removal of oxygen. They may also affect the amount and form of the nitrogen in the steel. The data obtained in many investigations indicate that nitrogen increases strain-ageing tendencies in certain steels, and some of these data also indicate that nitrogen raises the transition temperature. Nitrogen in the form of iron or manganese nitride is believed to contribute to embrittlement. The beneficial effect of aluminium on the toughness of steel at low temperatures has been ascribed by several investigators to the fixation of nitrogen as aluminium nitride.

At the United States National Bureau of Standards, G. W. Geil, N. L. Carwile and T. G. Digges* have studied the influence of nitrogen on the notch-toughness of heat-treated 0·3 per cent carbon steel at low temperatures. They used high-frequency furnace steels containing 0·3 per cent carbon with either 0·9 or 1·6 per cent of manganese and varying nitrogen. Nitrogen was introduced by adding calcium cyanamide to the molten charge. Some of the steels were treated by the addition of 0·10 per cent of aluminium in the furnace just before pouring. Charges of 200 lb to 300 lb were cast into 50 lb ingots and hot rolled to plate 0·5in to 0·6in thick. From the normalised plate, Charpy test-piece blanks were machined, having the dimensions 0·43in square by 2·16in long. These were heat-treated by quenching from 857 deg. Cent. in water at room temperature, and tempering at 538 deg. Cent., with subsequent air cooling, before final machining of the V-notch test piece. The specimens were then tested at temperatures ranging from −196 to +100 deg. Cent. The notch-toughness of the aluminium-treated steel was somewhat greater than that of the steel not treated with aluminium. Moreover, the steel treated with aluminium had a lower transition temperature than that to which no aluminium had been added.

Fig. 1 shows typical curves.

Further particulars of the steels represented are :—

	Steel A	Steel B
Aluminium addition, per cent	0·1	nil
Nitrogen, per cent, total ...	0·027	0·006
Nitrogen, per cent, as AlN	0·024	—
Oxygen, per cent, total ...	0·010	0·011
Oxygen, per cent, as Al_2O_3	0·009	—
Hardness, Rockwell C ...	27	27
Grain size at austenitising temperature	8	4 (50 per cent) 6–7 (50 per cent)
Impact figure at 20 deg. Cent. per foot pound	48	44
Transition temperature, deg. Cent.	−92	−44

Microscopical examination showed no free ferrite in the specimens, which all consisted of tempered martensite, so differences in transition temperatures were not due to variation in the amount of free ferrite present after hardening. Some specimens of steels without aluminium additions were quenched from 815 deg. Cent. to give them a smaller austenitic grain size, but their transition temperature was unchanged, so that grain size variation was not responsible for the differences observed in transition temperature. There was a trend in the direction of lowering of the transition temperature with increase in the aluminium nitride content of the steels treated with aluminium in excess of that necessary to combine with all the nitrogen and oxygen present. For example, three aluminium-treated steels containing 0·9 per cent manganese, in which all the nitrogen and oxygen was combined with aluminium, had the following properties :—

Nitrogen, per cent	Oxygen, per cent	Impact value at 20 deg. Cent., foot pounds	Transition temperature, deg. Cent.
0·005	0·005	69	−86
0·015	0·008	61	−85
0·031	0·008	49	−96

It appeared that the presence of aluminium nitride was somewhat injurious to the impact figure at room temperature but lowered the transition temperature and was thus beneficial to notch toughness at low temperatures. Alternatively, free aluminium in excess of that required to combine with the oxygen and nitrogen present may be regarded as slightly beneficial to notch toughness at room temperature and detrimental at low temperatures. It seems probable from the evidence obtained that aluminium oxide has no appreciable effect on the energy absorbed at room temperature or on the transition temperature.

The authors recognise the difficulty of assessing the separate influence of all the effects produced by aluminium, but it seems to be demonstrated that in this heat-treated carbon steel aluminium as an element in solution is not responsible for improved notch toughness at low temperature, but that the fixation of nitrogen as aluminium nitride is one factor, at least, in the beneficial effect of aluminium additions in lowering the transition temperature.

* *U.S. Bureau of Standards, Journal of Research*, March, 1952, page 193.

Gustav Tammann

METALLURGISTS will read with interest the Tammann Memorial Lecture delivered by Professor W. E. Garner before the Chemical Society and published in the *Journal* of the Chemical Society, May, 1952. It gives not only a vivid description of the life story of a famous physical chemist, but deals at some length with the results of his researches in the field of metallography. Sections on transformations from unstable to stable states, glasses, thermal analysis and the metals are of particular interest. In work carried out from 1898 onwards and summarised in *The States of Aggregation* (1925) Tammann showed that two important factors were involved in the transformation of unstable into stable states: the formation of nuclei of the stable phase within the body of the unstable phase, and the rate of growth of the centres of crystallisation so formed. These principles, worked out with organic substances, were applied to the solidification of metals. Below the melting point, nucleus formation rises to a maximum and then falls again owing, it was supposed, to increased viscosity of the liquid. Linear crystallisation velocity also passes through a maximum with falling temperature and then falls to a negligible value as the glassy state is reached, owing to retardation of molecular movement. Crystal size after solidification is determined by the relative value of these two factors. In his study of the "glassy state" Tammann dealt particularly with the phenomena which occurred during the "softening interval." He concluded that a glass could be regarded as a supercooled liquid for which the rotational movement of the molecules had been frozen.

In his introduction to *Metallographie* (1914) Tammann mentions the work of pioneers of metallography, such as Heycock and Neville, Osmond, and Roberts-Austen, but he saw that the field of inquiry into metallic alloys was so vast that it was not possible to make an impression on it in a reasonable time, working single handed. He also saw that simple new techniques were needed to enable rapid progress to be made. He found these techniques in taking cooling curves and in microscopical analysis, and there soon gathered round him a large number of collaborators. It thus became possible for him to make a valuable, though necessarily a provisional and incomplete, survey of a very wide metallographic field during his own lifetime.

Tammann relied on the quantitative interpretation of thermal analysis, verified by a study of microstructure and physical properties, in interpreting the constitution of a wide range of binary and ternary alloy systems. He was specially interested in the formation of intermetallic compounds, and attempted to deduce the rules which govern their formation. His interpretation was based largely on the position of the elements in the Periodic Table. Elements in the same natural group (i.e., vertical column) tend to form solid solutions, and form few compounds with one another, but when an element forms a compound with one member of a natural group, it tends to form compounds with all members of the same group. He studied the behaviour of solid solutions towards chemical attacks. Alloys consisting of mixtures of a less noble metal with a noble metal formed directly from the melt were resistant to attack by acids, oxidising agents, &c., when the percentage of the noble metal exceeded the "Parting limit." This did not apply to electrodeposited alloys. From this work

Tammann developed the conception of an ordered distribution of the atoms of a solid solution on a "super-lattice," the electro-deposited alloys, prepared at room temperature, being in a more haphazard or disordered state.

Tammann began research on the cold working and recrystallisation of metals with O. Faust in 1910 and continued to publish papers on this subject until he retired in 1938. His interpretation of the effect of cold work owed much to the earlier work of Ewing and Rosenhain. He explained recrystallisation as a process of nucleation and grain growth and emphasised the important part which may be played by intercrystalline films of impurity, for example, oxides. Such films stabilise the polycrystalline structure. On cold working the continuity of the film is broken and crystal growth can pass the old grain boundaries. Cold working followed by recrystallisation thus tends to the production of large crystal grains. This, though far from the whole truth, is a factor to be taken into account in the production of single crystals.

These researches constitute a part only of Tammann's varied activities mentioned in the Memorial Lecture, in which Professor Garner has given a worthy appreciation of one who helped to lay the foundations of physical chemistry in the last years of the nineteenth century.

Creep-Resisting Magnesium Alloys

INVESTIGATIONS with the object of improving the creep-resisting properties of magnesium alloys have been in progress in Britain, Germany and the U.S.A. for many years. In the development of these alloys the rare-earth elements have played an important part. Quaternary alloys of magnesium, zinc, rare-earth metal and zirconium have been developed which to a considerable extent maintain their room temperature properties at 205 deg. Cent. Results obtained with sand-cast and extruded alloys of magnesium and the rare-earth metals have been published by K. E. Nelson and F. P. Strieter,[1] and also by T. E. Leontis.[2] More recently, Leontis has reported on the effect of thorium up to 50 per cent on magnesium in the cast and extruded conditions.[3] Thorium increases the strength of magnesium alloys over a wide range of temperature. The outstanding characteristic of magnesium-thorium alloys is not their room temperature strength, but their high creep resistance at 250 deg. Cent. At this temperature the resistance of magnesium-thorium alloys to creep is stated to be the highest so far observed in any magnesium alloy. The improvement is much greater at 205 deg. and 250 deg. Cent. than at 315 deg. Cent.

One unsatisfactory feature of the sand-cast magnesium-thorium alloys is their relatively coarse grain size, which reduces strength and ductility at room temperature. The grain size can, however, be effectively reduced by the addition of zirconium with attendant improvement in mechanical properties. Leontis has demonstrated the effect of zirconium on magnesium-thorium and magnesium-thorium-cerium alloys in a recent paper.[4] Zirconium has a marked refining influence on the structure of magnesium-thorium alloys. The coarse columnar structure is changed to fine equiaxial grains. Besides improving the room temperature properties, zirconium increases the creep resistance of the magnesium-thorium alloys at 200 deg. to 250 deg. Cent., and its beneficial effect is evident up to 370 deg. Cent. The optimum thorium content appears to be 3 per cent, but more work is required to establish the preferred amount of zirconium; about 0·7 per cent is usual. Thorium increases the solubility of zirconium in magnesium, cerium decreases it. The addition of cerium to the magnesium-thorium-zirconium alloys is considered not to be beneficial. Addition of zirconium does not produce any corresponding improvement in the strength or creep properties of the extruded magnesium-thorium-zirconium alloys. Some properties of the sand-cast alloy, solution-treated and aged, in comparison with other compositions are shown in Table I, and some properties of the same magnesium-thorium-zirconium alloy as extruded, heat-treated and aged are shown in Table II.

TABLE I.—*Comparison of Properties of Some Magnesium Alloys in the Sand-Cast, Heat-Treated and Aged Condition.*[1, 3, 4]

Composition of alloy, per cent	Tensile properties at 20 deg. Cent.			Tensile properties at 205 deg. Cent.			Tensile properties at at 315 deg. Cent.			Loads in tons per square inch, giving 0·2 per cent extension in 100 hours at	
	Y.S.	T.S.	E	Y.S.	T.S.	E	Y.S.	T.S.	E.	205 deg. Cent.	315 deg. Cent.
Mg+3·2 Th	4·4	9·1	4	3·3	7·3	13·5	2·9	6·6	16·5	3·1	1·3
Mg+3·34 Th+0·94 Zr	8·4	13·0	4	6·2	10·8	21·3	5·7	8·6	9·7	5·0	1·4
Mg+3 Mischmetall+3 Zn+0·7 Zr	7·1	9·8	3	4·4	9·4	21	3·6	5·4	50	3·3	0·6
Mg+9 Al+2 Zn+0·2 Mn	11·6	18·7	2	4·9	7·6	36	2·2	3·6	108	0·6	0·19

Y.S.=yield strength and T.S.=tensile strength in tons per square inch; E.=elongation per cent on 2in.

TABLE II.—*Properties of Magnesium, 3·34 Per Cent Thorium, 0·94 Per Cent Zirconium Alloy as Extruded, Heat-Treated and Aged (Leontis)*

Temperature, deg. Cent.	Tensile properties			Load giving 0·1 per cent extension in 100 hours
	Y.S.	T.S.	E	
20	5·2	14·1	19	—
205	4·6	9·2	32	4·8
260	4·4	8·8	34	1·8
315	4·1	7·2	19	0·6
370	2·0	3·6	53	—

Y.S.=yield strength, T.S.=tensile strength in tons per square inch, E=elongation per cent on 2in

[1] *Trans. Amer. Foundrymen's Assoc.*, 1950, Vol. 58, page 400; also Vol. 59, April 23, 1951.
[2] *Journal of Metals*, November, 1951, page 987.
[3] *Journal of Metals*, March, 1952, page 287.
[4] *Journal of Metals*, June, 1952, page 633.

Zinc Coatings

UNDER the heading of "Galvanising in the U.S.A.", three papers appear in *Stahl und Eisen* for July 3, 1952, on the zinc coating of tubes, wire, sheet and strip. These papers were presented at a Conference on Galvanising on March 21, 1952, and led to a discussion which was also reported. They consist of reports and observations by European specialists who visited American plants under the auspices of the Organisation for European Economic Co-operation.

The first paper, on "Hot-dip Galvanising of Tubes," by R. Haarmann, deals with the properties of the material to be galvanised, with fluxes, and the technique of the galvanising bath as illustrated by the procedure at several works. The treatment of the tubes after galvanising and disposal of the waste products are also dealt with. In hourly rate of production, zinc consumption and economy of material, the leading European tube galvanising establishments are on an equality with corresponding American organisations. The main difference was shown in the galvanising of 3m long tubes, to serve as conduits for electric cable. These form a minor part of production in Germany. Whether or not the American equipment and practice will be applied in the German industry (which usually deals at the same time with a variety of products beside tubes) depends on local circumstances and is a matter for trial and decision in each special case.

"American Methods of Coating Steel Wire and Steel Wire Products" are described by P. Hillesheim in the second paper. The preparation of the wire and several zinc-coating processes are referred to. No great advantage in quality was recognised over German galvanising processes, but in production there was a large gap in favour of American practice. Large-scale planning and effective standardisation make the process simpler and under better control, thus leading to still higher production.

In the third paper, on "Galvanised Sheet and Strip," W. Brachmann describes and examines the American practice of sheet and strip galvanising. The satisfactory production of galvanised sheet is largely dependent on the quality and mechanical treatment of the original steel. In America, rolling is mainly carried out in continuous strip mills. The tendency in the development of galvanising is to make it a continuous process, and it is held that in course of time, Europe must follow this trend. There are two ways of further development: improvement of the processes employed at present and continuous galvanising of cold-rolled strip. It is only a question of time before the economical continuous process replaces the methods of sheet galvanising more usual at present. Meanwhile, however, the continuous process produces sheets which are not so soft as those produced by the older methods. Since in Europe, deformation of the sheet must often be undertaken by hand, it is essential to obtain a sheet which is as soft as possible. The continuous process also is not so adaptable to deal with a variety of products. Moreover, the development work on continuous installations has not yet reached a final stage, judging by the regard paid by different firms to their individual opinion on the construction of the plant.

All the works gave close attention to the surface quality of the galvanised sheets. Points which the author found to merit consideration were the importance of a cold pass in the preparation of the surface to be galvanised, the advantage of a neutralising treatment (with sodium cyanamide) after pickling, supplementary treatment of the galvanised sheet by "galvannealing," whereby the hardness of the galvanised coating is increased and phosphate treatment of the surface as a base for painting. Uses of galvanised products, different in many ways from those usual in Europe, were noted, and a study of these questions will evidently receive considerable attention in Germany.

All three papers are well illustrated by diagrams and photographs; and acknowledgement is made to the Hot-Dip Galvanisers' Association at Oxford, as well as to the appropriate section of the O.E.E.C., for their energetic assistance in preparing for and carrying out the visit.

BRITISH CAST IRON RESEARCH ASSOCIATION.—We have received from the British Cast Iron Research Association, a copy of the latest number of its *Journal of Research and Development*. The publication contains reports of two interesting research investigations on the harmful influence of some residual elements in magnesium-treated nodular cast irons and their neutralisation by cerium, and on quantitative spectrographic analysis of slags. The journal regularly publishes reports of investigations completed by the research and development departments of the British Cast Iron Research Association, there being six issues annually. It can be obtained from the Association's headquarters, Bordesley Hall, Alvechurch, Birmingham.

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QUALITY

SOME time ago there was found, when excavating a bombed site in St. Swithin's Lane, London, a very neat bronze folding rule giving evidence of the quality of workmanship attained by Roman instrument makers. It had endured for upwards of sixteen centuries and was still in good condition. A relic of this kind may cause us to reflect upon the importance of quality and upon the ceaseless need to maintain, in our products, that quality which has for long characterised British products and, in particular, British engineering products. There is, indeed, no more commendable activity than that which is directed to constant improvement in quality, and few among us will doubt that a great part of the foundations of quality lies in education and training. We are now, it is true, in possession of materials, tools and techniques which were undreamt of when that unknown Roman instrument maker fashioned his folding rule, but we need much more than tools and techniques. We need, above all, that pride in craft which is one of the most precious and rewarding of human qualities. A growing tendency of our times can be found in the accent placed on salesmanship. That we have something highly important in good salesmanship cannot be doubted, but much more important is good workmanship, and this can only be achieved where there are quality workmen. Too many of our citizens are prepared to leave the matter of workmanship to fend for itself, forgetting that unless we can go on creating and encouraging good workmen, the foundations upon which our standard of living depends must crumble. A vital pillar in these foundations has, in the past, been apprenticeship. Not long since, the director of training in a famous American machine tool plant described apprenticeship as "our priceless heritage." He went on to point out that "from the beginning of man, apprenticeship has been the principal means by which he has perpetuated all of his skills and knowledge. From early apprenticeship practice has come much of our formal educational systems. It has been the principal source of the basic philosophies and almost indispensable skills and traditions that have made possible the arts and crafts leading to our present standards of living."

Apart from the vital matter of the inculcation of skills and knowledge, is the equally important matter of quality in the person trained. We have, in recent times, witnessed the stupidity and lack of self-discipline which has produced what are called "apprentice strikes." Nothing could be more indicative of deterioration in human quality than action of this nature among youths who are acquiring experience fitting them to play an honourable part in national and international life. We are, indeed, immeasurably indebted to those craftsmen of old time—and not so old time—who set their work above everything. Men of whom Kipling was thinking when he wrote that:

> "They did not preach that their God will rouse them a little before the nuts work loose.
> They did not teach that His pity allows them to leave their job when they damn-well choose."

Every man among us who has gone through the discipline of an apprenticeship is aware of its value in the formation of character, apart altogether from its inestimable value in teaching a skilled trade. To forget the importance of effort is to forget the importance of character, since what we give out in effort returns to us—as has been well said—in character. It is here that the value of apprenticeship is seen in the contribution which it makes to human quality, and in this connection it is not possible to overstress the importance attaching to foremen. They are the indispensable non-commissioned officers of technical industry and constitute vital ingredients in the attainment of quality not only in the product, but in the producer. Quality product can only be obtained from quality personnel, and it is a true saying that the worth of a man is measured not so much by the quality and quantity of the work which he must do, as by the quality and quantity of the work which he actually does.

There remain to be considered, in the attainment of quality, the character of management and particularly the devotion of management to the interest of all those associated in industry. It is here that human qualities can make all the difference between success and failure, and it is surely a predominant necessity in those who lead that they should also be those who know. We occasionally find a lack of discernment similar to that of the fool who fancied he played upon the organ when he only blew the bellows. The leader of industry must be under no such illusion and he can only be truly successful when, instead of propelling men by his authority, he draws them by his example. A further and vital test of the quality of management lies in its ability to select and promote quality men. It is, of course, easier to determine the quality of a material than the quality of a man. George Bernard Shaw has remarked that "There are only two qualities in the world, efficiency and inefficiency, and only two sorts of people, the efficient and the inefficient." It is very true, but, what is more important—and much more difficult—than laying down definitions of human qualities, is to propose means whereby the inefficient can be rendered efficient. Surely a practical approach is found in the wider recognition, by management, of the vital importance of selecting and encouraging those whose services as leaders are most likely to have the effect of promoting efficiency and good team work. Here, personality is even more important than talents. "Höchstes glück der Menschenkinder," says Goethe, "ist nur die Persönlichkeit." The manager must always be what is called a sportsman, since, possessing this invaluable quality, he will be the better equipped for picking his team. "In the ultimate analysis," says a shrewd American, "the game of business is won not by star quarterbacks, but by the co-operation of a corps of men and women working in harmony and a common spirit of endeavour, as a smoothly functioning unit. Management's greatest challenge in its internal problems is to create such a team." Nothing is more requisite in the creation of such a team than quality in its constituents, and we may remember how it has been said of great batsmen that their quality is revealed in their ability "to dismiss the last ball from their memory—with all the troubles associated with it—applying their minds wholly to the next ball." If, in the factory and the office, we all sought to follow the lead of such batsmen, there would be no shortage of quality.

APPLIED RESEARCH

ONE of the more debated questions to-day is whether this country, despite its fine record of scientific investigation of the highest quality, is holding its own in the field of technical application. Recent debates in Parliament show that many conclude that it is not; hence, the various proposals put forward as a remedy. If this conclusion is valid, the call for appropriate action must be ranked as urgent in view of the tight financial situation in which the country has been placed by the march of events. It is therefore timely to consider what needs to be done, whether for the improvement of the industrial machine itself, or in taking whatever steps may be necessary to improve the quantity, or quality, of those entrusted with the task of technical application.

Fundamental research is normally looked on as a university task, just as applied research is the duty of industry; but things do not work out quite so simply as that. It is not hard to find in the great industrial firms research leaders of such high capacity as to be rightly left to follow to the end any lines of investigation, which, though not to be found in any formulated research programme, suddenly seem to offer a prospect of opening up new and useful industrial developments, or of extending the scope of scientific theories in ways which might have seemed at first sight more naturally appropriate to a university laboratory; a wise director of research will encourage and support the men who show this high ability. Equally, it is by no means uncommon for scientific investigators at universities to reveal genius for appreciating practical issues and for pursuing them to successful ends. Of this perhaps the most striking example was Kelvin, whose scientific study of the then maritime compass, as well as of the marine sounding gear, led to exceedingly practical and useful inventions.

It is true that no hard and fast boundary line can be drawn between fundamental research and that which should be classed as applied. Indeed, the drawing of hard and fast lines has its difficulty in most human affairs. But in the workaday world the customary mode of division is good enough, and the problem posed to British industry at the present time is whether the staff engaged on applied research is large enough or good enough for its job. Recent official inquiry suggests that it may be neither, and that prompt action to meet the situation should be taken. Those with personal experience in the direction of research organisations in the non-university field can hardly fail to have been impressed to find that it is a tiny nucleus of a staff which seems to be able to keep the whole team going; it is these few people who have the sudden flashes of insight coupled with the genius to see how to circumvent the apparently unsurmountable difficulty and who give inspiration to the rest. Their numbers may be less than a tenth of the whole, but however capable and wisely chosen may be the others, it is the little band of leaders who act as the spearhead. The normal recruitment of staff will be from the abler men leaving the universities each year; those with special flair for leadership will reveal themselves with little delay. In the House of Lords' debate early in June, to which reference was made at that time in these columns, Lord Woolton, after confessing himself as not satisfied that British industry was making sufficient use of science, or that it was properly staffed to do so, went on to urge that active steps should be taken to train an officer class in technology. That view was subsequently endorsed by Lord Hankey, who pointed to the precedents offered by the Imperial Defence College, and the Administrative Defence College, and advocated the creation of a similar post-graduate college for both scientists and technologists. It seems that the Ministry of Education has some such action in contemplation, but any idea that a "University of Technology" could serve both purposes is surely mistaken. There is no short cut; one cannot find the virtues of a university and of a specialist technical college in any such organisation. Earnest endeavours now being made to broaden the education and interests of young engineers are best furthered by the use of existing universities for training at undergraduate level, and for the available technological institutions, strengthened as necessary, to provide full opportunity for post-graduate study, their lecturers being largely borrowed from industry and having, therefore, full knowledge of current industrial practice.

To sum up the situation, it may be accepted that there is no single type of educational institution which can possibly supply everything that is needed. For the research worker the university gives the best early training. In certain branches of engineering work this is appropriately followed by post-graduate study in a College of Technology; in other branches by experience in an industrial research laboratory or a specialist workshop. But whether in research or development, the staff concerned are part of a common endeavour to apply the knowledge gained by the scientist in fundamental research (wherever carried out) into a form useful to British industry. More of such workers are needed. To improve recruitment, whether in quantity or quality, it is important that the interest and sympathy of the general public, especially of parents and schoolmasters, should be aroused and maintained; any steps to ensure this will certainly deserve the encouragement and support of engineers.

Short Notices

Alternating Current Machines. By Professor H. Cotton, D.Sc., M.I.E.E. London: Cleaver Hulme Press, Ltd., 42a, South Audley Street, W.1. Price 10s. 6d.—In this book the author sets out to explain alternating current machines on different principles from the usual students' textbook. His treatment of the rotating magnetic field is intended to appeal to the practical engineer, whose main need is to acquire a sound physical concept of the processes involved, without having to explore the mathematical analysis that the specialist might desire. Accordingly the reader needs little mathematical ability beyond simple multiplication and division, except in Chapter IV, which covers the induction motor. Here numerous examples are given to illustrate the special operating conditions of the induction motor rotor. Special emphasis is given to polyphase commutator motors and the repulsion motor in an effort to remove the difficulty that students sometimes experience in understanding the operation of these machines.

Multi-Motor Traction for Cranes. By R. A. West, B.Sc. (Eng.), A.M.I.E.E. London: Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, W.C.2. Price 21s.—This book is a companion to the author's previous work, *Electric Traction for Cranes*, and, it is assumed that the reader is familiar with the latter book. In developing methods of design for multi-motor drives the author discusses the characteristics of motors and crane structures and proceeds to examine thirty different kinds of drive. A variety of d.c. and a.c. motor drives are dealt with. The problem of maintaining correct alignment between different parts of the structure is examined: the solution, using selsyn systems, is given and there is a separate chapter containing an analysis of the power-selsyn drive and the behaviour of worm gears. When two or more slipring motors are used to drive the travelling motion the rotor circuits must be kept independent and three simple control systems which have been developed are described.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

THE FUTURE DEMAND FOR COAL

SIR,—Mr. John Fox says it is a pity that I did not pay sufficient attention to the Federation of British Industries' pamphlet on National Fuel Policy before writing my letter of June 27th. It was just because I had studied it that I wrote. I challenged the rather pessimistic conclusions of that document and suggested a more logical way of forecasting coal consumption.

To put it briefly, my view is that aided by the increased efficiency in electricity production (if the industry is allowed the freedom to expand), the use of the new domestic grates and more modern gas appliances, the net home coal consumption in 1961 will be nearer 4 tons per head of the population than the 5 tons estimated by the F.B.I. Forecasts are best made from long-term experience rather than from recent trends.

For some reason, Mr. Fox introduces the controversy on thermal efficiency, utilisation efficiency and so on, yet curiously enough he says it would seem prudent to await the report of the Ridley Committee. However, as he has raised these issues, may I reply to his four assertions.

If Mr. Fox will refer to another part of Sir John Hacking's speech, he will see that there are other views and that the utilisation efficiencies of both gas and electricity *when everything is taken into consideration*, are approximately equal at 19 per cent (the efficiency of electrical utilisation is, of course, increasing rapidly).

Although I do not agree with the fantastic suggestion that 10,000kWh a year would be required to provide comfort heating in the average council house, at no time have I advocated the exclusive use of electricity for heating. It is quite economical in a small flat (like my own), in small houses where the inhabitants are out all day, or where there are aged people who cannot fetch and carry. In very many cases, however, a smokeless fuel stove incorporating a hot water boiler is probably the best for use in the winter, but certainly not in the summer.

Until gas can be produced economically from the low grade fuels used by power stations or open grates can use this type of coal without all the extra expense and trouble entailed in coal transport, stoking and smoke production, we are not in a true position to compare the respective merits of electricity, gas or solid fuel when used in the home.

Where process steam is required by an industry for, say, over 100 hours a week, and there is a perfect balance between heat and power requirements it will probably be possible to make a case for back pressure turbines, but I should like to know from Mr. Fox how many such cases exist, if there are as many as he infers, and what has stopped the adoption of this method of generation ere now?

R. E. GAMLEN

Brighton, Sussex, July 18th.

FIRES IN PASSENGER TRAINS

SIR,—Apropos the leading article in THE ENGINEER of May 23, 1952, on the above subject, I am somewhat at a loss to understand the objections of the Railway Executive. Surely all that is required is additional exits which could be used in an emergency to assist passengers to leave the train more rapidly.

This is a usual provision on all aircraft, buses and motor coaches, and I do not see that their provision need affect the seating capacity one iota. The emergency breakdown equipment in trains is already housed in cupboards which

can only be opened by breaking a small glass panel, and I suggest that a similar arrangement could be adopted to enable a few windows to be jettisoned in an emergency.

In the case of the Huntingdon fire, this would have avoided the necessity for passengers to break windows and leap through, with the attendant risk from broken glass.

T. G. IRVING-SMITH

Woodchurch, Kent, July 18th.

[Lord Leathers announced in the House of Lords on June 18th, that the Railway Executive was fitting a door on the corridor side of all new sleeping coaches; that in each sleeper compartment there would be a window which would open to provide an emergency exit, and that a centre door would be fitted to all new centre-corridor coaches.—Ed. THE E.]

BRITISH LOCOMOTIVE PERFORMANCE AND EFFICIENCY TESTS

SIR,—Referring to Dr. Tuplin's letter in your issue of July 18th, I hardly think we need to await an official statement as to why the figures of coal per drawbar horsepower hour, obtained in the controlled tests, are so much lower than those recorded with the same class of locomotive in the interchange trials of 1948. In any test with a service train the steady steaming conditions are liable to frequent interruption, and in 1948 the working of locomotives was left, very largely, to the vagaries of individual drivers. To show to what extent this kind of condition beset the "B1" engines, I append a table setting out some details from the official report. Three different engines of the class were concerned, and four different drivers. To my mind it is the relatively low proportion of journey time in which the engines were under power that provides most of the answer. The figures in the table are the averages for the two return test trips over each route.

Route	Bristol to Plymouth	Marylebone to Manchester	St. Pancras to Manchester	Perth to Inverness
Engine No.	61,251	61,163	61,251	61,292
Length of run, miles	127·3	206·1	189·9	118·1
Average speed on running time, m.p.h.	43·8	38·7	44·7	34·0
Total time including stops, min	193	346	271	234
Time under power, min	133	231	199	143
Percentage of time under power to total time	68·8	66·5	73·4	61·1
Average d.b.h.p.	682	672	579	616
Coal per square foot of grate area per hour (time under power), lb	97	80	69·3	88·5
Coal per d.h.p-hour, lb	3·96	3·32	3·34	4·01

O. S. NOCK

Bath, July 21st.

SIR,—In order to avoid any misunderstanding, I feel that comment is necessary on the particulars given by the table on page 63, THE ENGINEER, July 11th, which sets out certain indicated and drawbar horsepower characteristics of the W.R. "Hall" class engine.

The term friction horsepower, given to the difference between the indicated horsepower and drawbar horsepower values, is not, strictly speaking, correct. If reference is made to the graphs 35 and 36, also 22 and 23, Bulletin No. 1, it will be noted that these specifically refer to the cylinder or indicated powers and to the corresponding tractive efforts and drawbar horsepowers on the "level." Such being the case, the difference between the horsepower values represents the total power required by the locomotive itself when running on a level tangent track under given conditions. No mention is made of the friction horsepower, except indirectly, inasmuch as it forms part of the total resistances of the locomotive. Frictional horsepower, as such, is the difference between the indicated horsepower and drawbar horsepower when these are determined on a stationary testing plant, the latter being really the effort measured at the tread of the drivers. In this manner the actual frictional resistances are obtained. The relation between the two powers mentioned is rather complex, due to the influence of speed and rates of cut-off, which, in combination, affect mechanical efficiencies as a percentage of the cylinder power actually developed at the tread of the drivers. In practice, mechanical efficiencies may be said to vary between the limits of 95 and 75 per cent, but these are only very approximate figures.

As my friend remarks, the powers absorbed by the locomotive seem high, though it must be remembered that, while this is especially so when only 1090 i.h.p. is developed, the speed is 60 m.p.h. as when the higher power of 1480 i.h.p. is shown. This does not necessarily denote a lower mechanical efficiency, but rather that the power required by the locomotive at this speed is independent of the indicated power and serves to show why coal rates per drawbar horsepower hour increase with light trains, because a large part of the power developed in the cylinders is expended on the locomotive itself, while the fuel used is all charged to the power required by the trailing load, i.e., the train.

E. C. POULTNEY

Haverstock Hill, N.W.3, July 12th.

TECHNICAL OFFICERS IN THE ARMY

SIR,—I would like to comment on the statement in your leading article on the technical training of Army officers, to the effect that the highest ranks are open to a technically trained officer, either as a commander or a staff officer.

While this may be the official attitude when it is required to induce applications for technical training, it is very far from being the fact. A glance at the current Army List will show that hardly any technically qualified officers have reached General's rank, or are employed in any but technical posts. Indeed, one exceedingly distinguished officer in the last war refused to consider officers of a certain combatant technical corps for appointments in command of brigades or larger units. Moreover, even in that corps it will be found that few officers who have devoted themselves to engineering as opposed to military duties have attained the highest ranks.

As long as this attitude persists in military circles there is, in my view, no possibility of the Army being competently served by its engineers.

K. H. TUSON

London, S.W.1, July 11th.

CENSUS OF PRODUCTION, 1948.—Among the final reports on the Census of Production for 1948—which have just been published by H.M. Stationery Office—is one entitled "Marine Engineering (Volume 4, Trade B)" Its price is 3s.

The Outlook

(*Contributed*)

No intelligent citizen, particularly if he be connected with the engineering industry, can fail to feel apprehensive as to his future when he views a situation where rapidly rising costs synchronise with rapidly increasing external competition. Without awareness of what must follow from an insane refusal to face the facts, we live in a fool's paradise. It is not that we lack sombre warnings. What is lacking is such attention to these warnings as shall move us to take action directed to averting calamity. There are many signs that by the end of 1953—or earlier—reduction in the accumulation of orders for heavy engineering material will have been such as to bring a stark realisation of the vital need for new business. If, between now and then, there is to be a continuance of the spiral in costs accompanied by further shrinkage in the value of sterling, the effect on our standard of living is likely to be such as we have not hitherto dreamed of. We do not enjoy any monopoly of technical skill. We are obliged to import much of our raw material. We cannot claim to be so industrious, individually, as we were in the past. Masses of our people have allowed themselves to be lulled into the monstrous belief that security can be attained without effort. It is very difficult, moreover, to bring home to the average citizen the fact that we have lost the stabilising effect of those precious invisible exports and foreign investments which hitherto provided powerful support to our credit. Our credit—or rather its restoration in whole or in part—is now dependent solely on our own efforts. It is as futile to contemplate income without efforts as it is to contemplate a harvest without ploughing. This is not a mattter of politics or of legislation; it is something as immutable as are the laws of nature. "There is no good," says Lowell, "in arguing with the inevitable. The only argument available with an east wind is to put on your overcoat."

Now that large claims are being made for increases in wages and reduction in hours of working, it is well that we should all realise the circumstances in which we stand, and it is specially urgent that those who put forward such claims should remember words uttered by a prominent trade unionist at the Trades Union Congress in 1946. Referring to measures which the Government was then introducing, he pointed out that the success of such mesures depended solely upon efforts. "You cannot," he said, "fill bellies with Acts of Parliament or Treasury Notes." Heavy lies the responsibility on the leaders of trade unions, since upon them rests the obligation, above all, of thinking for their members. They can only be successful in leadership where they realise their duty to the nation as well as to the men from whom they receive their salaries. Equally responsible are industrial managements, since upon them rests the obligation to labour ceaselessly for the welfare of those whose living depends, in an appreciable degree, upon the skill and devotion of those who manage. The safety of the men at the oars rests upon the skill and awareness of the steersman. We read too much about "management" and "workers." There can be no more barbaric travesty than to suppose that the obligation to work is sectional. All men in industry are either workers or loafers, and it is no exaggeration to affirm that the happiest men are those who really work. We get a

hint of this in the derivation of the word "diligence," which is from the Latin "diligo," to love. A truly diligent man loves his work, just as did that Great Western Railway engine driver who, retiring after forty years' service, remarked that: "If I had my time over again, I should like the same job. I have enjoyed it." There is to-day on all hands far too much vituperative hostility, too much truculence and too little tolerance. This sort of thing affects national industry much as friction affects machinery: it reduces efficiency and leads to breakdown. We should recall the words of Dr. Johnson in that place where he speaks of the effect of "a perpetual reciprocation of malevolence." Such a condition approximates to barbarism alike in government and in industry and its exponents should be utterly discredited. As the Americans say, "It doesn't pay off." We have to stamp out, also, all vestiges of false security, remembering that the step from complaisancy to bankruptcy is as short as that separating the sublime from the ridiculous.

No thinking man can doubt that the engineering industry is facing times which, already difficult, are certain to become more difficult still. What we need, among other things, is truly concerted action. For action to be successful it must have tools, and of these the most powerful are the invisible ones. We do well to ponder Napoleon's declaration that in war, moral considerations make up three-quarters of the game ("A la guerre, les troise quarts sont des affaires morales, la balance des forces réelles n'est que pour un autre quart"). It is just the same in industry, where imgination, conscientiousness and diligence are among what Napoleon refers to as the "affaires morales." Without them no industry can be safe for those whose living is bound up in it. This is a consideration which ought to be paramount in the mind of every man who is engaged in industry, irrespective of the position which he may fill. There is a certain ratio between the diligent and the lazy which, if diminished, leads to collapse. What we want—and we want it very badly—is a realisation of the need to use the invisible tools which have been referred to. Only by such realisation shall we stop the rot. We are not yet a second-rate nation. Indeed, if we become one it will be due not so much to our circumstances as to our folly. Let us take heart from valiant and victorious struggles in the past and remember that at a time of deep national anxiety, George Herbert uttered a call which may well encourage us to-day:—

"O England, full of sin but most of sloth;
Spit out thy phlegm, and fill thy breast with glory."

The Modernisation of a 132kV Circuit Breaker

By C. J. O. GARRARD, M.Sc., M.I.E.E.

In the early days of the Grid a nominal rupturing capacity of 1500MVA was considered adequate for 132kV switchgear but, as the system grew, the fault level at points near large generating centres rose until many switching stations needed circuit breakers of 2500MVA or even 3500MVA capacity. To avoid the expense of widespread replacement means were found of modifying the 1500MVA circuit breakers, thereby increasing their rupturing capacity. This article describes the modernisation of one form of 132kV circuit breaker which was originally supplied for the Central England and South-West England areas of the Central Electricity Board.

THE 132kV grid of the Central Electricity Board was designed on the assumption that the fault level would be 1500MVA, and all the circuit breakers originally installed had a nominal breaking capacity of that value. Experience showed, however, that this assumption could not long be maintained. Even before the war the fault level at points near the greater concentrations of generating plant had risen above 1500MVA, while since the end of the war the expansion of generating capacity has led to a corresponding increase in the general fault level of the grid, so that to-day only the more outlying parts can be operated at a level of 1500MVA; the majority of stations require breakers of 2500MVA capacity and in some 3500MVA is required.

The circuit breakers and other apparatus in the 132kV substations represent an investment of many millions of pounds; it is therefore gratifying that it has proved possible by comparatively modest alterations of the majority of the breakers to make them suitable for the increased duty now imposed upon them. At the same time their performance in point of speed and certainty of operation has been improved and the breakers have been made capable of withstanding rigorous testing according to up-to-date standards.

This article describes the successive modifications of one type of 132kV breaker supplied originally in 1928 for the Central England and South-West England areas of the Central Electricity Board.

The general appearance of the original breakers is shown in Fig. 1, and the interior of one phase in Fig. 2. Each tank was 6ft 6in in diameter and had a detachable domed top. The bushings were paper condensers with oil-filled porcelain shrouds, both outside and inside the breaker. In addition to the bushings there were attached to the inside of the top plate two porcelain post insulators, each carrying a fixed contact, the two being connected together electrically. The moving contact system consisted of two cross bars, which engaged with the fixed contacts on the posts and with two more on the bushings. There were thus four breaks per pole; the fixed contacts were fitted with stress shields, but there was no form of arc control device.

The moving contacts were carried by two plastic rods attached to blocks which slid up and down two tubular guides attached to the top plate. The blocks were raised by two links hanging on a pair of levers pivoted to the top plate near its centre. These levers in turn were actuated by two toggle levers driven by bevel gears and a shaft passing through the top plate. The closing mechanism consisted of a solenoid with solid cast iron yoke and steel plunger.

As the circuit breaker in this form was never tested, there is not much accurate information about its performance. The opening time was about 0·1 second and the closing time 0·9 second. The speed of break was approximately 5ft per second, so that it may be taken that the arcing time was 10 to 20 half-cycles. The breakers (about 120 of them) operated satisfactorily for several years in positions on the grid where the fault current probably approached the value equivalent to 1500MVA. No case of failure was reported.

The appearance of the new edition of B.S. 116 in 1937, in which for the first time the conditions for the testing of circuit breakers were laid down, together with the knowledge that the fault level of the grid was steadily rising, made it necessary to examine the rating of these breakers. Experience with plain-break circuit breakers at lower voltages showed that if the 132kV breaker were to be rated according to the new specification, some redesign and the fitting of arc control devices would be necessary. Arrangements were therefore made to modify the internal parts of the breaker, as is shown in Fig. 3.

It was found that side blast arc control pots could be accommodated in the existing tanks and with the existing bushings. As the four-break construction was complicated and apparently unnecessary, it was abandoned and a two-break design adopted. The arc control pots (Fig. 4) were adapted so that they could be fitted to the existing bushings without removing them from the breaker and all the existing moving contact parts were used with the exception of the contact bars. All the parts were provided with very large adjustments, as it was known that the centres and angles on which the existing bushings were mounted varied not a little. The conversion of the breakers was carried out on site without removing the breaker top plates and in a relatively short time.

During tests upon the converted breaker several of the porcelain lower shrouds of the bushings were broken because of the lateral force due to the reaction of the blast from the arc control pots. A synthetic reson impregnated paper lower shroud was therefore designed which could be substituted for the porcelain shroud, without disturbing the remainder of the bushing. The short circuit tests showed that the breaker now had a breaking capacity in accordance with B.S. 116, substantially greater than 1500MVA. The opening time was 0·084 second, the arc duration varying from six half-cycles at 100 per cent of the normal rating to eleven half-cycles at 10 per cent of this rating, while the closing time was 0·72 second.

The conversion of almost all the installed breakers to this construction was completed by 1938; and a large number of new breakers, to the modified design, was supplied in subsequent years.

While this was being done, however, it again became necessary to see whether the breakers described above could have their rating still further increased, this time to 2500MVA. The total number of breakers installed was by then approximately 200, representing a value at current prices of the order of £2,000,000, so that the possible saving by up-rating instead of replacement was very large. An examination of the question and some preliminary tests showed that there was a good prospect of being able so to redesign the breaker, retaining the majority of the more expensive components, as to make it suitable for a rating of 2500MVA. The tests described below have demonstrated the feasibility of this project and shown that the performance of the modified breakers satisfies present-day standards of performance.

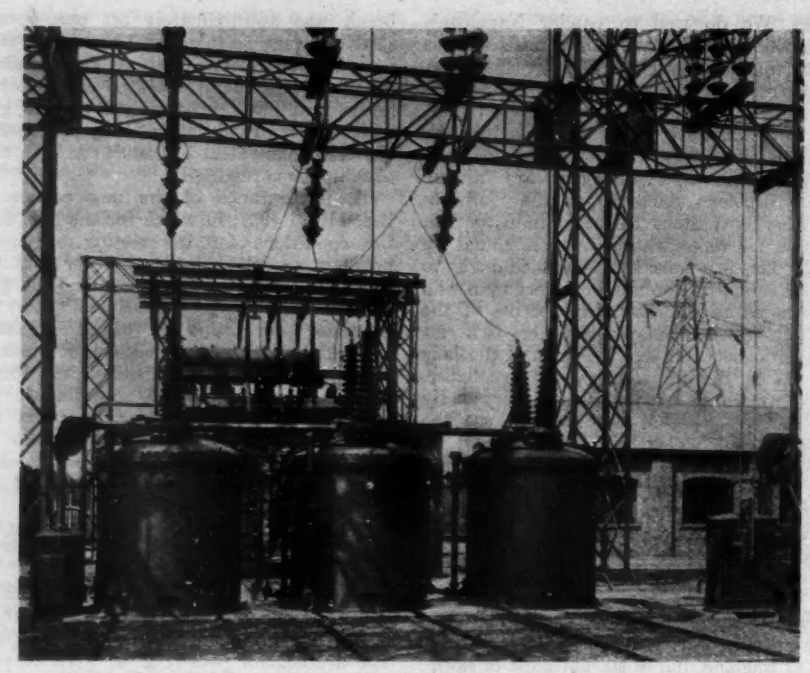


FIG. 1—THE ORIGINAL 132KV CIRCUIT BREAKERS

It was decided that the redesigned breaker should satisfy the following conditions:—(*a*) As much as possible of the existing construction should be retained in order to reduce the cost of modification; (*b*) the modifications should be capable of being carried out on site; (*c*) the modified breaker should have a rating of at least 2500MVA at 132kV; (*d*) the total break time should not be substantially greater than 0·06 second (3 cycles); (*e*) the breaker should be suitable for three-phase or single-phase rapid reclosing cycles; (*f*) having regard to the limitations of existing test plants, the design of the breaker should be such as to allow it to be tested at breaking currents corresponding to its rating and with recovery voltage as nearly as possible equal to that encountered in service.

The most important decision of principle was to adopt resistance switching—that is, to arrange the breaker so that interruption is carried out in two stages. In the first stage, the main contacts are opened and bridged by non-inductive resistors, while in the second the residual current in the resistors is broken. It may be recalled that this principle has two advantages. First, the switching in of the resistors exercises a favourable effect on the interruption of the circuit, particularly when small currents are being interrupted under conditions of high fault circuit severity. Secondly, the assurance given by the resistors that the recovery voltage of the circuit is divided equally between the two breaks of a double-break breaker makes it legitimate to employ methods of part testing, i.e., testing one break of a pair at a time, which effectively doubles the capacity to which a given test plant can be used to subject a breaker under test.

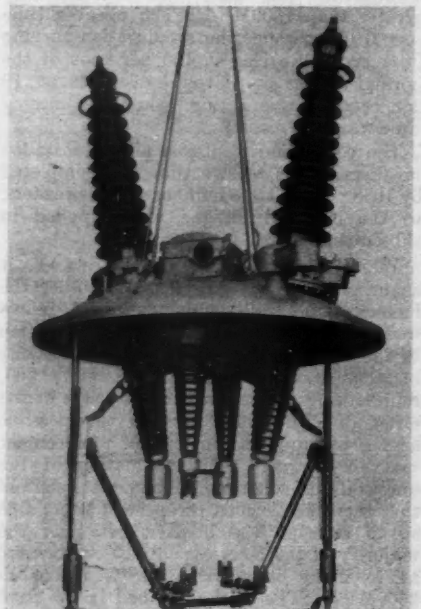


FIG. 2—MECHANISM OF ORIGINAL CIRCUIT BREAKER

The general appearance of the modified breaker is shown in Figs. 5 and 6. The new mechanism has been so designed that it can be erected inside the tank on site, and with only small alterations to the tank; it is fixed to the flanges provided for the original mechanism. It consists of a central guide which houses the accelerating springs and inside which moves a sliding member carrying at its lower end the insulator for the moving contacts. This insulator is of "Permali," and is guided by a bracket also of "Permali."

The contact is moved by a main lever connected to it by two swinging links which, in turn, are actuated by links and a bell crank lever attached again by links to a pull rod which connects the three phases. The main lever carries a further set of links which connect it with the shock absorber by which the energy of the contacts is absorbed at the end of the opening stroke. The whole mechanism is made as far as possible of duralumin forgings with ball bearings.

The arc control pots are very similar to those which have been in successful service on the 1500MVA breakers. Each pot consists of an impregnated fabric tube with horn fibre inserts forming the necessary cavities and vents. An annular contact is provided at the mouth of the pot through which passes the moving contact, and between this and the main arcing contact is connected the switching resistor.

The choice of the value of the switching resistor is a matter of some difficulty. So far as the division of the voltage between the two breaks is concerned, the value is not critical. The value of the residual current which flows through the resistors after the extinction of the main arc must be such that it is interrupted reasonably quickly after the moving contacts have left the arc control pot—that is, its value should not exceed a few tens of amperes. The lower limit of the value of the resistance per phase is thus of the order of $\frac{132{,}000}{1{\cdot}73\times 50}=1500$ ohm.

Another point is that the resistance per phase, if it is to be effective in aiding the extinction of the main arc, must have an appreciable effect upon the rate of rise of the restriking voltage under onerous conditions of operation.

If we assume for the sake of a rough estimate that the inherent damping of the system from the point of view of the restriking transient is low, i.e., that the shunt resistance in the circuit is high, and that the resistance of the circuit breaker arc itself is also very high, it can be shown that a switching resistance approximately equal to the surge impedance of the system, $\sqrt{(L/C)}$, would reduce both the peak value of the restriking transient and its rate of rise by approximately 50 per cent.

In the case of a 132kV breaker of 2500MVA breaking capacity, operating at its full rating, the effective inductance participating in the restriking transient is

$$L=\frac{132^2}{2500\times 314}=0{\cdot}025 \text{ H.}$$

The network capacitance may be taken to be of the order of 5000 $\mu\mu F$, so that the surge impedance is

$$Z=\sqrt{\frac{L}{C}}\simeq\sqrt{\frac{0{\cdot}025\times 10^{12}}{5000}}\simeq 2200 \text{ ohms.}$$

The corresponding values for operation of the breaker at 60, 30 and 10 per cent of its ratings are

$$\frac{2200}{\sqrt{0{\cdot}6}}\simeq 2850 \text{ ohms,}$$

$$\frac{2200}{\sqrt{0{\cdot}3}}\simeq 4000 \text{ ohms,}$$

and

$$\frac{2200}{\sqrt{0{\cdot}1}}\simeq 7000 \text{ ohms respectively.}$$

It follows that if the resistance value is chosen to be reasonably effective at the full rating of the breaker it will tend to be correspondingly more effective at fractional ratings. In practice, however, it is found that the lower value of the resistance is subject to very severe limits set by the maximum permissible temperature rise and the maximum practicable dimensions of the resistors.

From these considerations it was decided that the resistance per phase should be approximately 2000 ohms or 1000 ohms per break. Preliminary calculations and tentative coil designs, based upon the characteristics of available material, led to the final value being fixed as 950 ± 25 ohms. Each complete coil consists of twenty-four pancakes, the manufacturing limits of which were fixed as $39{\cdot}5\pm 4{\cdot}5$ ohms. The pancakes are sorted according to resistance and assembled selectively in order to meet the tolerance on the resistance of the complete winding. The pancake coils are wound with nickel-chrome strip, $\frac{1}{4}$in wide and 0·007in thick. The interturn insulation is a strip of "leatheroid," $\frac{1}{4}$in wide and 0·005in thick,

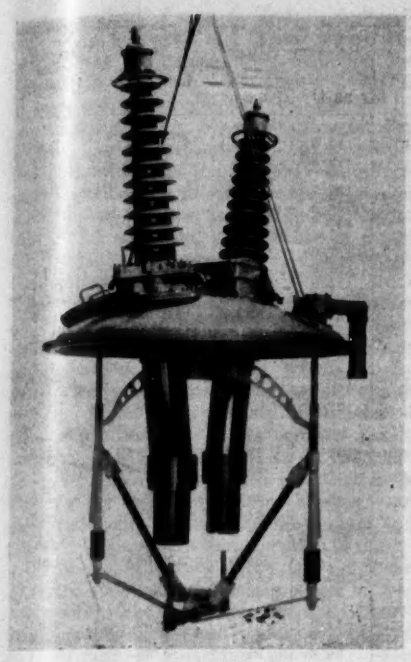


FIG. 3—MODIFIED CIRCUIT BREAKER MECHANISM

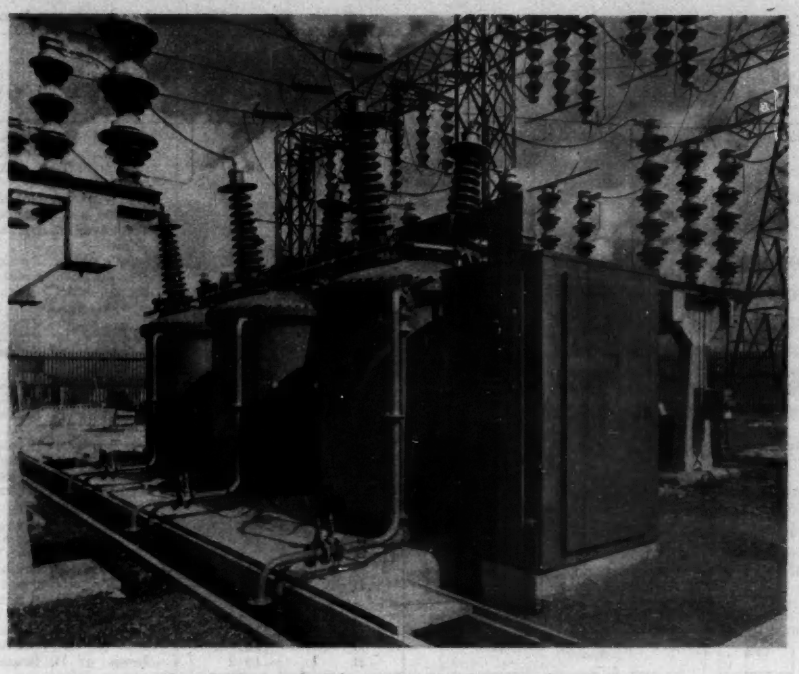


FIG. 5—MODIFIED THREE PHASE CIRCUIT BREAKER

wound together with the conductor. The pancakes are separately impregnated and baked, after which they are threaded on a "Permali" rod, each alternate pancake being reversed so as to provide a substantially non-inductive winding. The ends of the coils are joined by electrical spot welding in carefully controlled conditions. The complete winding is mounted in a plastic tube with suitable terminals.

In the present case the design of the resistors from the point of view of heating was based upon the following assumptions:—(*a*) that the breaker performs a sequence of operations of break—make break—make break in rapid succession; (*b*) that in each case

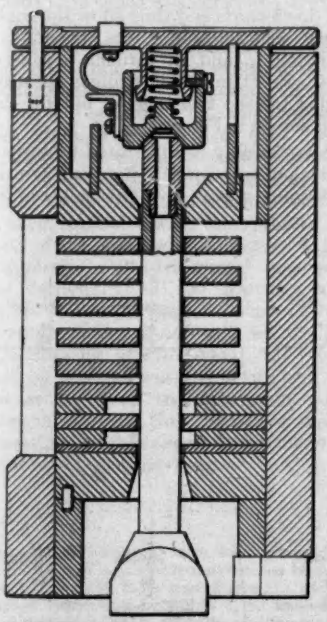


FIG. 4—SECTION THROUGH ARC CONTROL POT

the same phase is the first to clear; (*c*) that the recovery voltage across the first phase to clear is 1·5 times the phase to earth voltage, i.e., 114kV; (*d*) that in each break operation one and the same arc control pot of the first phase to clear always clears 0·005 second before the other;* (*e*) the duration of the resistance current during a break operation is 0·045 second and during a make operation 0·06 second (these figures are derived from the results of preliminary tests).

The chances against any phase of any breaker being, in fact, subjected to this combination of adverse circumstances are probably in the order of several millions to one; the assumptions in themselves therefore constitute a considerable factor of safety, which, as described below, is augmented by so designing the resistors that the heating calculated on these very unfavourable assumptions is about one-third only of the maximum permissible temperature rise.

The heat capacity of the pancake consists of that of the resistance tape together with that of the insulation (leatheroid), with which it is in immediate contact. Heat losses by conduction or convection of the oil, and the heat capacity of the oil itself, were neglected in the calculations. The highest hot spot temperature in a complete resistor is reached by the pancake of highest resistance (44 ohms) in one complete coil of a pair both having the lowest resistance (925 ohms). The heat generated in such a pancake is

$$H = RI^2t$$

$$= 44\left(\frac{E}{925}\right)^2 t \times 10^6$$

$$= 51 \cdot 5\, E^2 t \text{ watt-seconds,}$$

where E is the voltage across one complete resistor in kilovolts and t is the duration of its application in seconds.

The total heat in the pancake generated during a cycle of operations is

$$H = 51 \cdot 5 \Sigma E^2 t \text{ watt-seconds.}$$

On the above assumptions, one complete resistor of a pair will be subjected to 114kV for 0·005 second, followed by 76/2=38kV for 0·04 second on each break operation and to 38kV for 0·06 second on each make operation.

* This is equivalent to assuming that for 0·005 second the full restriking voltage appears across one set of contacts of the pair while the arc path between the other set remains conducting. It is somewhat doubtful whether in fact this condition is physically possible, but as its possibility has been suggested, account has been taken of it.

It follows that

$$\Sigma E^2 t = 114^2 \times 0 \cdot 005 \times 3 + 38^2 \times 0 \cdot 04 \times 3 + 38^2 \times 0 \cdot 06 \times 2$$

$$= 541$$

so that

$$H = 51 \cdot 5 \times 541 = 27{,}900 \text{ watt-seconds.}$$

Each pancake consists of approximately 0·96 lb of "Brightray" tape of specific heat 0·1 lb and 0·12 lb of "leatheroid" of specific heat 0·3. Its total heat capacity is thus $(0 \cdot 96 \times 0 \cdot 1 + 0 \cdot 12 \times 0 \cdot 3) \times 4 \cdot 2 \times 453 \cdot 6 = 250$ watt-seconds per deg. Cent. temperature rise.

The hot-spot temperature rise of the resistor is thus 27,900/250=112 deg. Cent.

This appears to be a moderate figure for "leatheroid" in oil, having regard to its being based upon extremely unfavourable assumptions which are rarely, if ever, likely to be realised in practice. To provide a check,

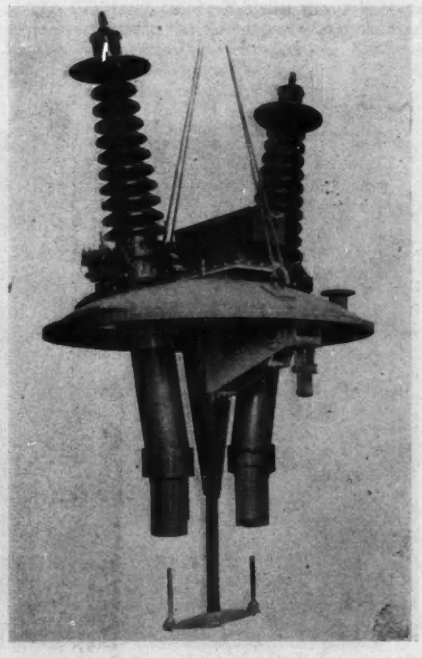


FIG. 6—MECHANISM AS FINALLY MODIFIED

Proving Tests on Modernised 132kV Circuit Breaker

Test No.	Percentage of declared breaking capacity	Operation	Current broken, kA	Nature of test	Applied voltage	Recovery voltage kV	Recovery voltage Per cent	Arc duration, half cycles	Opening time 1/100 sec
6507	5 per cent, symmetrical	B	0·57	Single - phase	Breaker closed	139·5	105·7	4·14	7·36
		B	0·57	test on both	Breaker closed	139·0	105·3	4·20	7·36
		B	0·57	breaks of B phase	Breaker closed	140·8	106·6	4·11	7·33
6506	10 per cent, symmetrical	B	1·10	Single - phase	Breaker closed	137·7	104·3	3·38	7·06
		B	1·08	test on both	Breaker closed	136·8	103·6	3·46	6·98
		B	1·09	breaks of B phase	Breaker closed	136·8	103·6	3·30	6·77
6505	30 per cent, symmetrical	B	3·05	Single - phase	Breaker closed	127·0	96·2	2·68	6·35
		B	3·02	test on both	Breaker closed	128·0	97·7	3·10	6·63
		B	3·05	breaks of B phase	Breaker closed	131·0	99·3	2·68	6·44
6502	60 per cent, symmetrical	B	6·30	Single - phase	Breaker closed	128·0	97	2·90	6·28
		B	6·30	test on both	Breaker closed	127·2	96·3	2·86	6·15
		B	6·38	breaks of B phase	Breaker closed	128·8	97·5	2·71	6·21
6501	80 per cent, symmetrical	B	8·7	Single - phase	Breaker closed	125·4	95	3·29	6·63
		B	8·6	test on both	Breaker closed	127·7	96·7	3·14	6·41
		B	8·6	breaks of B phase	Breaker closed	128·8	97·5	3·20	6·69
6499	100 per cent, symmetrical	B	11·1	Three - phase	Breaker closed	30·5	23·1	1·32–1·8	5·40
		B	11·2	test on both	Breaker closed	31·5	23·8	1·46–1·88	5·53
		B	11·1	breaks of each phase	Breaker closed	31·2	23·6	1·16–1·52	5·21
6503	100 per cent, symmetrical	B	10·6	Single - phase	Breaker closed	85·6	64·9	2·7	6·19
		B	10·5	test on one	Breaker closed	85·3	64·6	1·78	5·20
		B	10·5	break of B phase	Breaker closed	85·1	64·4	2·72	6·21
6504	100 per cent, asymmetrical (approx. 65 per cent d.c. component)	B	11·7	Single - phase	Breaker closed	85·8	65·0	1·60	4·97
		B	11·7	test on one	Breaker closed	85·0	65·0	1·44	4·88
		B	11·6	break of B phase	Breaker closed	87·5	66·3	1·61	5·18
6620	110 per cent, symmetrical	B	11·7	Single - phase	Breaker closed	81·6	61·8	1·30	4·98
		B	12	test on one	Breaker closed	82·8	62·7	1·90	5·54
		B	12·2	break of B phase	Breaker closed	80·6	61	1·80	5·54
			Current made, kA/ph						Making time 1/100 sec
6498	100 per cent	MB	31 24 24·5	Three - phase	18·8	—	—	—	12·71
		MB	21·9 29·9 24·6	test on both breaks of each phase	19·0	—	—	—	10·96
6500	60 per cent	MB	14·30	Single - phase	75·8	—	—	—	12·21
		MB	15·35	test on both breaks of B phase	76·4	—	—	—	10·47

however, a sample pancake assembly was tested as follows. The assembly consisted of four pancakes, one of which had a resistance of 44 ohms (i.e., the highest value), and a second a resistance of 36·8 ohms, the whole having a resistance of 925/6=154·5 ohms. A voltage of approximately 114/6=19kV was applied to the assembly for 0·16 second, giving a current of 125A. The heat generated in the 44-ohm element was therefore $125^2 \times 44 \times 0{\cdot}16 = 110{,}000$ watt-seconds, and in the 36·8-ohm element $125^2 \times 36{\cdot}8 \times 0{\cdot}16 = 92{,}000$ watt-seconds, as compared with the above calculated maximum operating figures of 27,900 watt-seconds. The "leatheroid" in the high-resistance pancake was found to be slightly discoloured and brittle, while that of the low resistance unit was completely unaffected. It may therefore be taken that a heat input of about 100,000 watt-seconds per pancake is permissible so that the design has a factor of safety of about $\frac{100{,}000}{27{,}900} \simeq 3\frac{1}{2}$ against excessive heating even under the most extreme operating conditions.

In a further test 37kV was applied to a similar assembly for 0·04 second, giving approximately the same heat input as before. The results as regards heating of the insulation were the same. The second test demonstrated also that the interturn and interlayer insulation of the resistors has a factor of safety at least 2 against electrical breakdown.

The operating mechanism (Fig. 7) is arranged to be suitable for solenoid or compressed air drive; at present solenoids are being fitted. The magnetic circuit consists of C-shaped laminations of $\frac{5}{16}$in mild steel with a total effective cross section of 81 square inches. The plunger also is laminated and slides in brass guides. The coil has 100,000 ampere turns and develops a thrust of about 5 tons with a momentary consumption of 33kW.

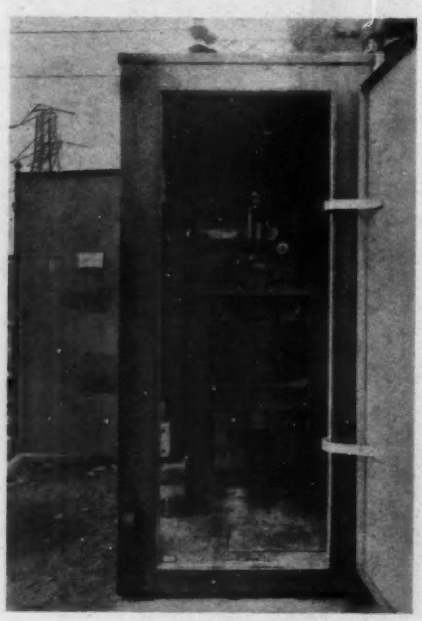


FIG. 7—OPERATING MECHANISM

The trip mechanism consists of a train of four links, L_1, L_2, L_3, L_4; a main operating lever OL, and two trip latches TL_1, TL_2, and is shown diagrammatically in Fig. 8. A swinging link L_5 provides the necessary constraint for the junction of L_2 and L_3, but permits the necessary freedom of movement to allow either links L_1 and L_2 or L_3 and L_4, acting in each case as a simple toggle, to break downwards and thus allow the contacts to open. The solenoid S acts upwards on the pin joining L_1 and L_2 through a roller and guides. Resetting and tripping springs are provided for the two toggles, but for clarity are not shown in Fig. 8.

The action may be illustrated by supposing the breaker to be open (Fig. 8*a*), trip latch TL_1 having operated. The solenoid upon

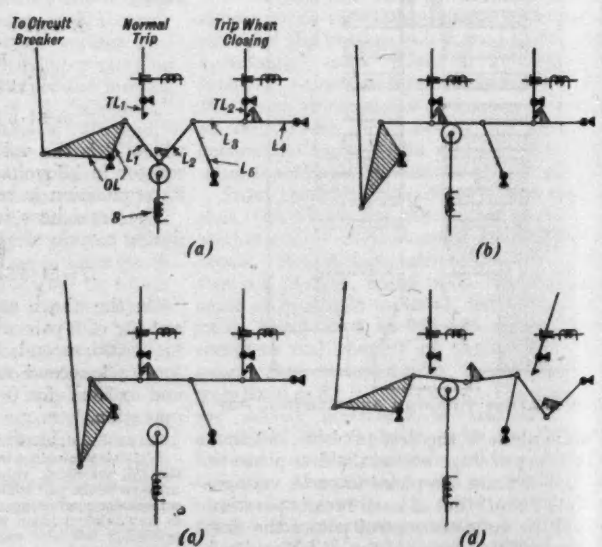


FIG. 8—DIAGRAM OF OPERATING MECHANISM

being energised, forces L_1 and L_2 upwards until TL_1 engages, and then closes the breaker, the mechanism then assuming the position in Fig. 8*b*. As the solenoid is de-energised, the plunger returns to its original position (Fig. 8*c*), and the mechanism is ready for a further tripping operation. During the time that the solenoid is energised, a set of auxiliary contacts operates to transfer any tripping impulse from TL_1 to TL_2, so that if, for example, the breaker is closed upon a fault, TL_2 operates and the toggle $L_3 L_4$ collapses.

On a rapid reclosing cycle, the breaker is tripped at first by TL_1; as the breaker opens, the solenoid is energised and the plunger moves up to meet toggle $L_1 L_2$, at the same time transferring the trip circuit to TL_2. If the fault persists the breaker is again tripped as soon as the contacts touch, this time by TL_2 and toggle $L_3 L_4$ (Fig. 8*d*). The mechanism is reset into the position of Fig. 8*a* by a resetting mechanism (not shown) attached to the solenoid plunger and actuated by its return to its position of rest.

Because of the very heavy current taken by the solenoid, it is broken in stages by two contactors. The first contactor opens, leaving the second closed and feeding the solenoid coil through a switching resistor. After a short interval the second contactor opens and finally breaks the circuit.

A very comprehensive series of proving tests was made with the modified breaker, to prove its breaking, making and short-time current carrying capacity according to B.S. 116. A selection of the test results is given in the table on page 132.

On all these tests the behaviour of the breaker was good, the only visible effect of the passage of current being a small amount of smoke from the vent. The burning of contacts and erosion of the arc control pot components were such as would be expected. On the making tests the breaker closed fully home, thus showing the adequacy of the closing mechanism. On all the breaking tests the duration of the arc during the breaking of the resistance current was observed; its value was between 1·5 and 3·5 half-cycles.

A test (No. 6537) was made at 140 per cent of the short-time current rating of 10·9kA, in which the duration of passage of the current was 4·9 seconds. The temperature rise of the contacts was 59 deg. Cent. A test (No. 6508) was made to check the voltage rating of the switching resistors. The moving contacts of the breaker were held with their tips level with the contacts in the throats of the pots and a voltage of 111·2kV was applied for 0·10–9 second between one phase terminal and the moving contact crossbar. This voltage is over twice the maximum voltage that could be applied to the resistor in practice, and the heating caused by the test was about two and a half times as much as the maximum possible heating in service. No evidence of charring, overheating or incipient flash-over of the resistor could be discovered.

MAGNETIC CLAMPS FOR WELDING ASSEMBLIES.—A useful form of adjustable magnet has been introduced by Donald Ross and Partners, Ltd., 1-3, Arlington Road, London, N.W.1, to facilitate the setting up and holding of work at different angles for assembly by welding, marking off, &c. The device consists simply of two magnetic blocks, which are 1in square by 2in long, connected by a pair of metal straps 3¼in long. The faces of the blocks can be adjusted to any angle to each other and locked by means of thumbscrews. A number of other forms of magnetic clamp for supporting parts for welding and other assembly work are made by the firm.

Pneumatic Tide Generator

By M. J. WILKIE, B.Sc., A.Inst.P.,* and G. A. J. YOUNG, B.Sc.†

The tide generator here described has automatic control and is intended for use on models of river estuaries. The air pressure in an inverted box at the seaward end of the model controls the amount of water drawn into the box from the model. A servo system operates a valve regulating the air pressure, in such a way that the water level just outside the box follows the desired tide curve which is drawn on a moving paper chart.

IN 1947 the Department of Scientific and Industrial Research set up the Hydraulics Research Organisation to study problems connected with estuaries, harbours, coast erosion, &c. Some work on these subjects was already in progress in the Engineering Division of the National Physical Laboratory, and the new organisation assumed responsibility for this. The programme of work for the new body included the construction of models of the rivers Severn and Thames. These models would be considerably larger than any previously constructed at the National Physical Laboratory, and there were disadvantages associated with the existing kind of tide generating mechanism that were thought to justify an attempt to develop a new apparatus. Three generators of this kind are now in operation. One is on the River Wyre model in the tidal model shed at Teddington. It replaced the displacer type generator previously on that model, when the vertical exaggeration of the model was doubled. The other two generators are on models of the River Thames, constructed by the Port of London Authority, at the Royal Victoria Docks.

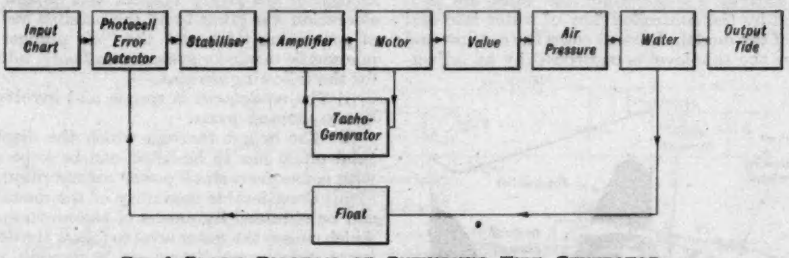


FIG. 1—BLOCK DIAGRAM OF PNEUMATIC TIDE GENERATOR

TIDE GENERATORS

The tide generators used by previous experimenters may be classified into two types, mechanical displacer types and hydraulic types, respectively.

Mechanical Displacer Types.—In these the tides are produced by raising and lowering a non-buoyant displacer immersed in the water in a tide box at the seaward end of the model. The earliest of these was that used by Reynolds on his model of the Mersey, and consisted of a hinged tray driven by a hydraulic motor. As models became larger a ballasted plunger suspended from a lever was used, the lever being operated through a mechanical linkage and epicyclic gear train. This allowed the stroke of the plunger to be varied cyclically so as to represent the lunar cycle of spring and neap tides. In order to reduce the variable load on the driving motor the system was balanced by weights suspended from a cam.

There are three main disadvantages of this type of tide generator. First, the motion of the plunger is predetermined by the design of the mechanical linkage and cannot easily be altered, so that only tides of "average" shape can be produced. Secondly, the tide produced depends on the mean tide level, or volume of water in the model, which has to be maintained by other means. Thirdly, the plungers can become very cumbersome and heavy and involve unwieldy balancing mechanism.

The first and third of these disadvantages were overcome in the tide generators developed in the Engineering Division of the National Physical Laboratory for the Forth and Wyre

FIG. 2—TIDE GENERATOR FOR RIVER WYRE MODEL

* Hydraulics Research Station, Howbery Park, Wallingford, Berks.
† Now at the British Hydromechanics Research Association, Netteswell Road, Harlow, Essex.

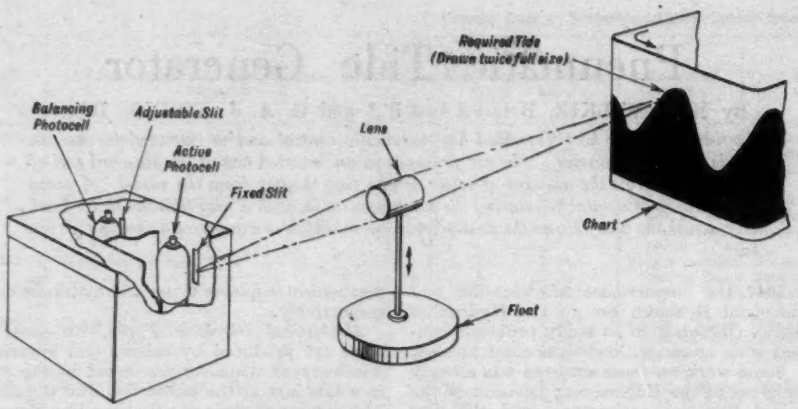


FIG. 3—CHART UNIT FOR THAMES PILOT MODEL

tidal models. In these the plunger was moved by a hydraulic ram so that balance weights were unnecessary. A hydraulic servo system caused the motion of the plunger to follow a cam, the profile of which would be altered to obtain the desired tide curve. A second cam superimposed the spring-neap cycle.

Hydraulic Types.—Here the tides are produced by the controlled flow of water into and out of the model. In most cases the outflow and hence the tide level is controlled by an adjustable weir, and many incorporate a step-by-step servo system actuated by the error between the motion of a cam and that of a float level indicator in the model.

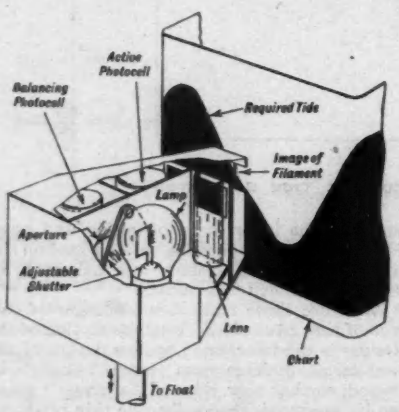


FIG. 4—CHART UNIT FOR WYRE AND THAMES MODELS

In the earlier examples the inflow was constant throughout the cycle and a simple rectangular weir was used. This system had two obvious disadvantages. First, on the ebb tide the weir had to discharge a maximum flow about twice the maximum tidal flow; and secondly, the behaviour of the automatic control system was complicated by the non-linear characteristics of the rectangular weir. These two disadvantages were overcome in later models by making the inflow proportional to the rate of rise of the flood tide and zero during the ebb, and by the use of a proportional weir. These modifications also reduced the maximum capacity and hence the power of the recirculating pump.

When preparing designs for the proposed models of the rivers Thames and Severn consideration was given to all the possible methods of generating tides and the "air plunger" or pneumatic displacer system was finally adopted for the following reasons:—

(i) The equipment is simple and involves no heavy moving parts.

(ii) The height through which the displaced tidal prism has to be lifted can be kept small with consequent small power consumption.

(iii) Considerable flexibility of the model tide can be obtained by means of the servo system which causes the water level to follow the desired input tide curve drawn on a moving paper chart. The amplitude, shape and period of tide can thus be readily varied over a wide range.

A mock-up of such a scheme was built in the basin of the old Shatt-el-Arab model at the National Physical Laboratory during 1948 and shown to be promising. Further work led to the designs described below.

THE PNEUMATIC TIDE GENERATOR

Principle of Operation.—A block diagram is given in Fig. 1. The desired tide curve is drawn on the input chart, which is moved at constant speed past the photoelectric detector. This compares the desired level with the actual level given by a float in the model, any error resulting in a voltage proportional to the error in magnitude and sign. This output is amplified and drives a motor-operated valve. An inverted box at the seaward end of the model extends to the model floor, except on the side facing the model. Here it ends an inch or two below the lowest low-water level, leaving a gap through which water can flow between box and model. Air is exhausted continuously from the box by a fan, but an accurately controlled supply of air is allowed to enter the tide box through the motor-operated valve, which, by regulating the air pressure in the box, controls the amount of water drawn from or released into the model and hence controls the model water level. The direction of operation of the valve and motor is chosen to reduce the signal from the error detector, and so the water level follows the input curve.

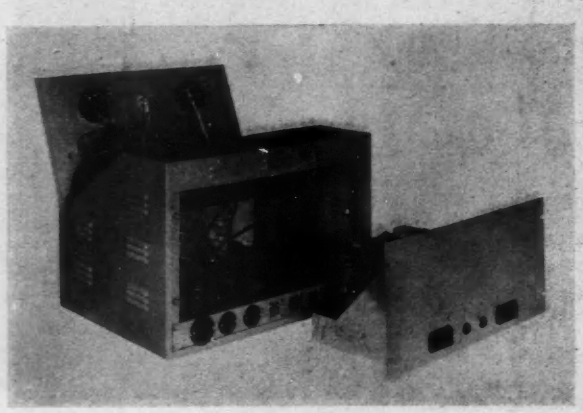


FIG. 5—CONTROL UNIT

The subsidiary loop shown on the diagram comprises a tacho-generator driven by the motor, feeding a voltage into the amplifier in opposition to the error signal. This results in the motor speed being proportional to the error voltage, and helps to stabilise the system. Without this loop the motor torque would be proportional to the error voltage. Further stabilisation is provided by an electrical net work inserted between the photocell and main amplifiers.

General Description.—A photograph of the generator in use on the model of the River Wyre is shown in Fig. 2. The wooden tide box, about 16ft by 13ft by 5ft, supports all the other units except the fan, which is fitted with a silencer and placed outside the building to reduce noise. The chart unit comprises the chart on which the tide curve is drawn, its driving mechanism, the float, photocells, lamp, optical system and pre-amplifier. The motor unit comprises the motor which operates the valve via a gearbox and cam, a relay which switches the motor armature current, and the tacho-generator. The control unit contains the power pack, amplifier and the switches and meters necessary for the operation and supervision of the tide generator. The equipment fitted to the Thames pilot model and to the Thames model is similar. The tide box for the former is of wood and is 17ft by 3ft 6in by 4ft 6in, and for the latter is of reinforced concrete 40ft by 12ft by 6ft.

The apparatus thus briefly described can be used over a wide range of model size. There are two forms of chart unit which are capable between them of coping with tides from 1in to 7½in total amplitude. The dimensions of the tide box have to be altered from model to model, and the valve and cam may require modification. The control unit is independent of model size.

DETAILED DESCRIPTION OF EQUIPMENT

Tide Box.—The design of the tide box is necessarily a compromise between the conflicting claims of space, power and time constant. In order to keep the power requirements of the fan to a minimum it is desirable for the box to have a large floor area so that the mean distance through which the water is raised each cycle may be small; but the motion of the water surface in the model then lags behind the motion of the valve and the lag increases as the floor area of the model is increased. The greater this lag, the more difficult it is to stabilise the complete servo system. Details of the calculations of power, time constant, and tide box dimensions are given in appendices.

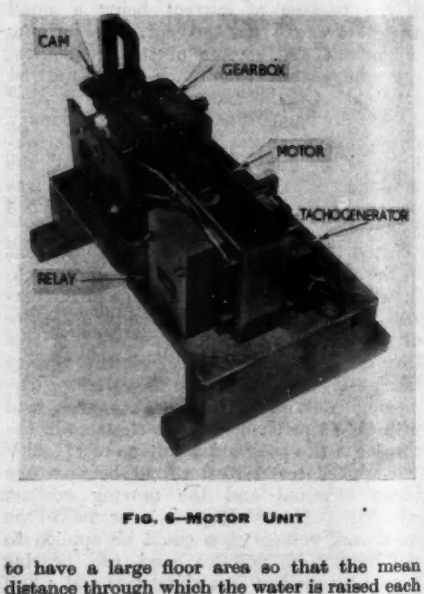


FIG. 6—MOTOR UNIT

The Chart Unit.—The chart unit used on the Thames pilot model is shown diagrammatically in Fig. 3. The input is drawn in the form of a black and white profile on 9in wide perforated paper which is driven by an ordinary recorder mechanism operated by a synchronous motor. A "Striplite" lamp and cylindrical Perspex lens illuminate a strip of the chart about ¼in wide, but are not shown on the diagram. A 5in f/4 lens throws a full-size image of part of this strip of chart on to a $\frac{1}{16}$in by 1in slit. The light which passes through

this fixed slit illumines a photocell. A second cell placed behind a slit of adjustable width receives light direct from the lamp. Baffles prevent this adjustable slit receiving light from the image and prevent the fixed slit receiving direct light from the lamp.

The two photocells are part of a bridge circuit which, by means of the adjustable slit, can be

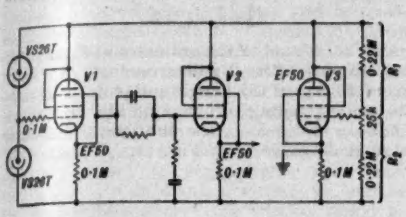


FIG. 7—PHOTOCELL AND PRE-AMPLIFIER UNIT

balanced for zero output when the image of the boundary between black and white lies across the middle of the length of the fixed slit.

The 5in lens is supported by a float in the water of the model, a parallel motion linkage limiting the possible motion of the lens to an almost straight vertical line. As the water level changes, the lens throws a different part of the image on to the slit, the linear movement of the image being twice that of the lens. When the complete generator is working the image of the profile will always be very near the middle of the fixed slit, and thus the amplitude of the input chart must be twice the desired tidal amplitude. The chart moves at 1in per minute, which fixes the horizontal scale of the input profile. The float is 8in diameter, built up of Perspex, and sinks about 1in into the water under the weight of the lens and linkage. The corresponding natural frequency is 3 c/s, well above the tidal frequency. The distance between float and lens is adjustable over a range of $\pm 1\frac{1}{2}$in, so that high water in the model may agree with high water on the chart.

This chart unit is limited to a tidal amplitude of about 3in. The amplitudes of the Wyre model and large Thames model are $7\frac{1}{2}$in and 4in respectively, and the chart unit used on these models is shown diagrammatically in Fig. 4. The paper and driving mechanism are the same as for the Thames pilot model, but the profile amplitude is equal to the desired tidal amplitude. The float supports a box containing a lamp, cylindrical lens, adjustable shutter and two photocells; flexible leads carry the power and the error voltage. The lamp is a straight filament headlamp bulb, rated at 12V, 24W, but run at only 6V. A cylindrical lens focuses light on to a strip of chart about $\frac{1}{16}$in wide. Its length is limited to 1in by extensions of the box. A photocell picks up the light reflected from the chart and a second cell receives light from the lamp through the adjustable shutter. As before, a bridge circuit is used and balanced for zero output when the strip of light falls half on the black and half on the white part of the chart.

The housing of the lamp and photocells is fitted with four ball bearings which, running on tracks machined in a brass plate, constrain the float and photocells to move on a vertical line. The movement of the housing is not quite smooth when the generator is in operation, presumably due to friction, although no appreciable roughness can be felt when the float is moved by hand. The alternative form of chart unit is therefore more suitable for small tidal ranges.

The float is the same size as before, but the total supported weight is greater, giving a depth of immersion of 1in and a natural frequency of $2\frac{1}{2}$ c/s.

The Control Unit.—As already stated, this houses the power pack, amplifier, a connection panel and the switches and meters necessary for operating and monitoring the generator. The amplifier and power pack are built on standard size Post Office relay rack panels. They are housed in a steel case shown open and with the power pack withdrawn in the photograph, Fig. 5. The connection panel, also a standard P.O. size, fits underneath the power pack and as far as is practicable is fitted with different types and sizes of plugs and sockets. Where this is inconvenient they are colour coded to facilitate correct interconnection between units.

The Motor Unit.—Fig. 6 is a reproduction of a photograph of the motor unit. The split field motor is just visible at about the middle of the far side of the unit. The tachogenerator at the near end and the gearbox at the far end are coupled to the motor by rubber couplings. The cam, which is also just visible, is mounted directly on one of the output shafts of the gearbox. The gearbox has three worm and pinion gears, each giving a speed reduction of 100 to 1 and each having an output shaft. Thus it is possible to obtain stepdown ratios of 100, 10,000 or 1,000,000 to 1. The 10,000 to 1 ratio is used here. The cam provided to linearise the relation between angle of rotation of motor shaft and water level gives a further stepdown of about 10 to 1.

The armature current is switched by a relay mounted on the near corner of the unit. Two microswitches are in series with the relay coil and are operated by small adjustable cams which rotate with the main cam. They thus act as limit switches which prevent overrunning of the cam.

ELECTRONICS

The circuit diagrams are shown in Figs. 7–9. The photocell bridge circuit is balanced coarsely by adjustment of shutter and slit and finely by the potentiometer. Gas-filled photocells were first tried, but the zero balance setting wandered. Vacuum cells have proved more stable and give quite as much output when used in this circuit. The values of the components in the filter network which stabilises the generator will vary from model to model.

The amplifier consists of two d.c. coupled stages, each a cathode-coupled pair of valves. The error voltage is applied to one grid and the tachogenerator voltage to the other grid of the first stage. The output from this stage is proportional to the difference between the inputs.

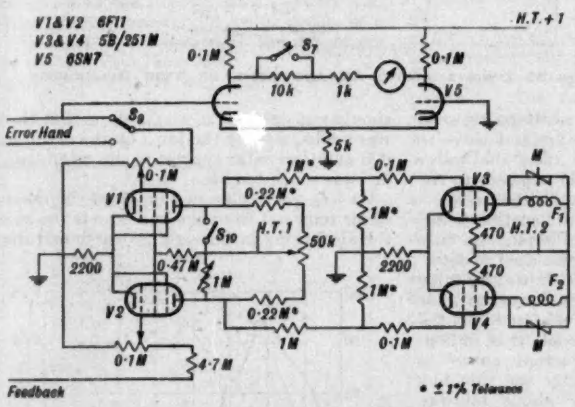


FIG. 8—AMPLIFIER FOR PNEUMATIC TIDE GENERATOR

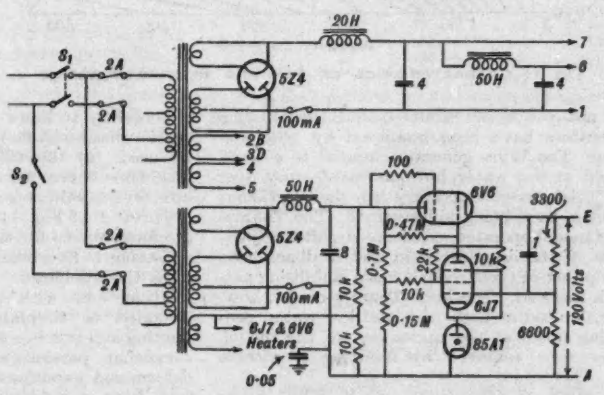


FIG. 9—POWER PACKS FOR PNEUMATIC TIDE GENERATOR

The anode load of each valve of the second stage is one field winding of the motor. When the circuit is initially balanced with zero input the current through each winding is the same, giving zero resultant field.

The power pack provides heater power for the valves, an unstabilised supply for the main amplifier, and a stabilised supply for the photocells and preamplifier. The relation between these circuits and the rest of the electrical parts is shown in Fig. 10. The tide level meter shown on this diagram has not yet been constructed,

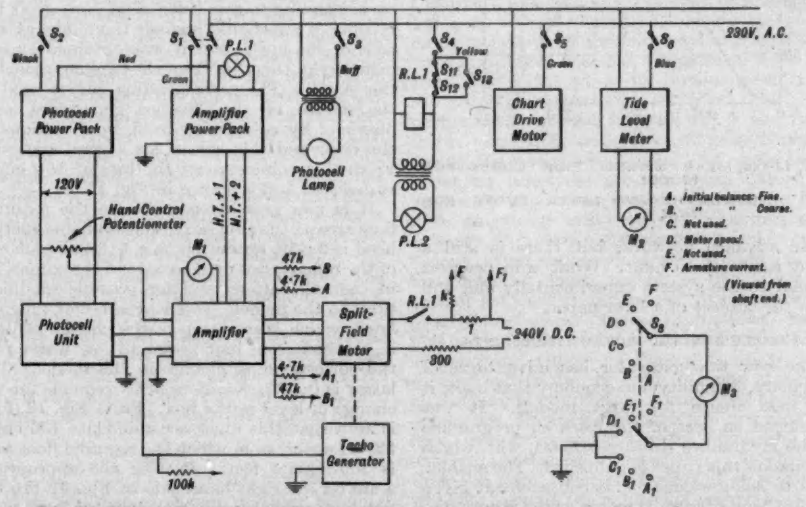


FIG. 10—INTER-UNIT DIAGRAM OF CONTROL FOR PNEUMATIC TIDE GENERATOR

although there is a meter available on the control panel.

The split field motor, and hence the water level, may be controlled by the hand control potentiometer (instead of by the error signal). This is useful when making the initial adjustments and when starting or shutting down the generator.

Stability

Owing to the complexity and non-linearity of the pneumatic and hydraulic components of the system a satisfactory theoretical analysis has not yet been obtained, and the existing generators have been stabilised by trial and error. The Wyre generator hunted to a small extent at low water, but was satisfactory over the tidal range necessary to the particular problem then being investigated. The Thames pilot model operated satisfactorily after adjustment of the amplifier gain and feedback. So far neither of these models has a stabilising network inserted. The large Thames model, however, hunted at both high and low water, producing bores at the upper end of the model. These were removed by inserting a suitable phase advance network, but there is still a slight tendency to hunt. Work is in progress to analyse the system experimentally and will form the subject of a later paper.

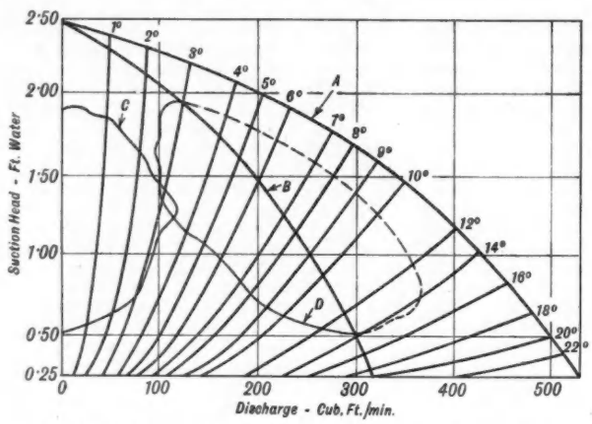


FIG. 11—CHARACTERISTICS OF FAN AND BUTTERFLY VALVE

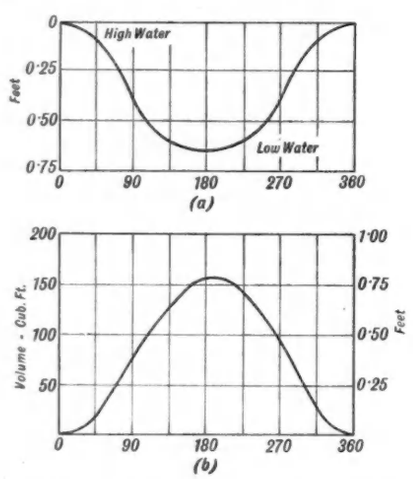


FIG. 12—(a) MEAN SPRING TIDE CURVE FOR MODEL
(b) VOLUME AND LEVEL CURVE FOR BOX

Conclusion and Acknowledgments

The new tide generator has advantages of simplicity, flexibility and economy that make it the first choice for large models. It was developed as part of the research programme of the Hydraulics Research Board, with whose permission this paper is published. The authors wish to acknowledge the encouragement given by Sir Claude Inglis, Director of the Hydraulics Research Station, and the assistance of the experimental and workshop staffs in the construction and testing of the equipment.

Appendix I

The Design of the Wyre Model Tide Box

This appendix will show how the Wyre box was designed to suit a fan that was available. Power economy and time constant are considered in the two following appendices, showing that although a smaller fan would have been adequate from the power aspect, the maximum time constant would have been about 50 per cent longer.

In order to determine the box dimensions it is necessary to know (*a*) the relations between suction head and flow for the fan and valve to be used, (*b*) the tide curve (i.e., the water level/time curve) for the model adjacent to the box, (*c*) the volume/time curve for the model.

Curve *A* of Fig. 11 shows the suction head/discharge curve for the available fan, the only resistance to flow being the orifice used to determine the discharge. Curve *B* shows the same relation, but with extra resistance to flow intended to simulate the resistance of the ducting and tide box of the model. It is, in fact, somewhat pessimistic, the actual curve as determined experimentally after the tide box had been constructed lying about midway between *A* and *B*.

To control the air flow into the box a simple butterfly valve is used, consisting of an elliptical brass plate pivoted inside a 5in diameter brass pipe so that it cuts off the flow when at 45 deg. to the axis of the pipe and offers minimum resistance to flow when parallel to the axis. The relation between head and valve opening is non-linear, but approximates to a straight line over the first 10 deg. to 15 deg. of opening. The family of curves representing the valve performance are shown on Fig. 11.

Fig. 12 (*a*) is a mean spring tide curve calculated for the model from data obtained from the River Wyre. Fig. 12 (*b*) is the volume curve corresponding to this tide; that is, it gives the volume of water that has left the model at any part of the cycle, and it was obtained experimentally in this case from the existing model of the Wyre. (The corresponding curves used in the design of the Thames generators were obtained by calculation from cross sections of the river and tide curves for several stations.) From this volume curve the rate of flow curve is deduced and is shown in Fig. 13 (*a*).

It is now possible to estimate the required flow area of the tide box. The available suction head is 2·45ft water. Of this, 0·5ft at each end of the range is not used to cover approximations in the calculations and for possible modifications to the model. This leaves 1·45ft range of head, which is made up of the change of level in the box from high water to low water plus the corresponding change in the model. The latter is 0·65ft, therefore 0·8ft remains for the change of level in the box. From Fig. 12 (*b*) it is seen that this must accommodate 156 cubic feet of water, from which the required floor area is 200 square feet. Putting the appropriate scale on the right-hand side of Fig. 12 (*b*), the volume curve also shows the change from high-water position of the water level inside the box.

In order to check on the suitability of the combination of fan and tide box, it is necessary to determine the total head/flow relation. Referring to Fig. 13, the head at any part of the cycle equals the head above high water in the box plus the head below high water in the model plus the head from high water in the box to high water in the model. That is

$$h_B = h_2 + h_1 + h_0,$$

which is the sum of the ordinates of Figs. 12 (*a*) and (*b*) plus 0·5ft. By determining h_B for, say, every 20 deg. of tidal angle and plotting against the corresponding ordinate of Fig. 14 (*a*) we obtain a closed loop, the ebb part of which is plotted as curve *C* of Fig. 11. If this curve should cut curve *B* it would show that the fan was inadequate for the job; on the other hand, if *B* and *C* were far apart it would mean that the fan was much too big.

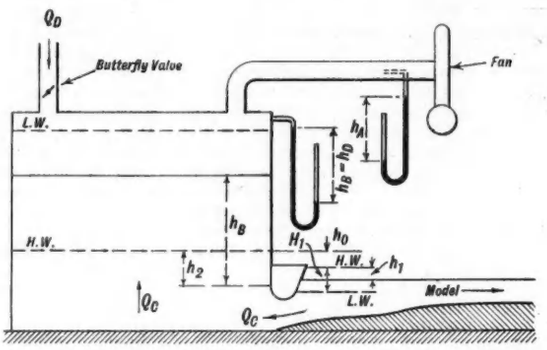


FIG. 13—DIAGRAMMATIC ARRANGEMENT OF TIDE GENERATOR

At any particular suction head the quantity of air removed from the box equals the sum of the air flowing in through the valve and the air displaced by the water entering the box. That is

$$Q_B = Q_D + Q_C$$

or

$$Q_D = Q_B - Q_C.$$

Q_B is given by curve *B* and Q_C by curve *C*, therefore Q_D may be determined and is plotted as curve *D*, the dotted portion of which corresponds to the uplotted flood portion of curve *C*. The intersections of curve *D* and the valve characteristics give the cycle of valve positions necessary to produce the desired tide. This cycle is plotted (full line) in Fig. 14 (*b*). From this curve the

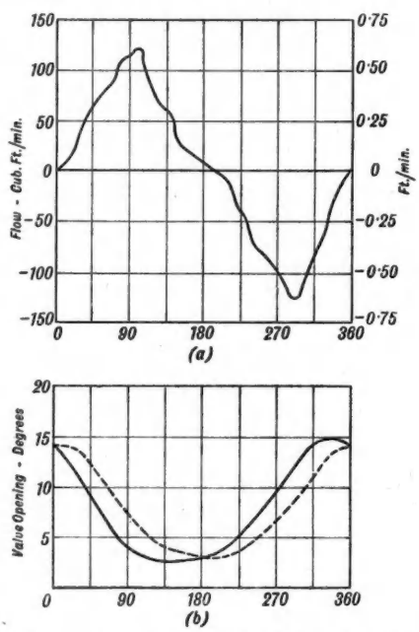


FIG. 14—(a) RATE OF FLOW CURVE FOR BOX
(b) VALVE READING CURVE

maximum rate of change of valve position can be determined and a suitable gear ratio chosen for the valve operating servo-motor. The dotted curve of Fig. 14 (*b*) shows the cycle of valve positions necessary to produce the tide curve if the period were infinite or there were no lag in the pneumatic system.

No mention has yet been made of the head required to accelerate the water and to overcome its internal friction. Calculation shows that the maximum acceleration of the water surface in the box is less than 10^{-5} times the acceleration due to gravity, and hence the head required is negligible. It is also possible to calculate that if there were a head of water in the box of 1ft, and the pressure in the box were suddenly raised to atmospheric, the water would flow out in about a second, so that at the normal rate of flow the friction would be negligible.

Appendix II

Considerations of Power Consumption

In designing the tide box and choosing the fan for a large model it is important to consider the maximum power absorbed by the fan and, hence, the size, capital cost and running cost of the fan and motor unit. This depends on (*a*) the maximum power required to generate the tide, and (*b*) the efficiency of the "pneumatic pump" system. The former is inversely proportional to the floor area of the box and the latter depends on the choice or design of a fan with suitable characteristics and the proper design of the ducting and valve.

Referring to Fig. 13 and Fig. 15, which is

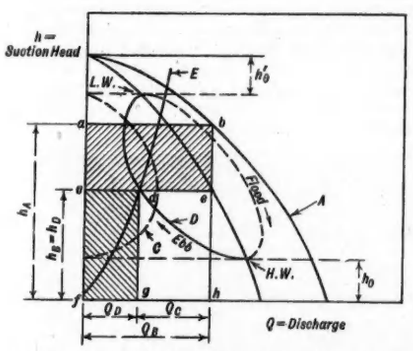


FIG. 15—Qh DIAGRAM FOR TIDE GENERATOR

based on Fig. 11, let us consider the point *d* on the operating loop curve *D*; this point is at about half ebb tide at which the power requirements will be about maximum. The curve *E* passing through this point represents the valve characteristic, i.e., the relationship between Q_D and h_D for the particular valve opening. The power used to generate the tide is proportional to the area of the rectangle *dehg*,

$$= Q_c h_B$$
$$= Q_c[h_0 + h_1(1 + {}^{S}/_{s})]$$

where ${}^{S}/_{s}$ is the ratio of the water surface area in the model to that in the tide box.

For a given model Q_c is determined by the model scales and then the power required is proportional to $h_0 + h_1(1 + {}^{S}/_{s})$. The margin h_0 is required in order that control action can still be obtained in the region of high water, and in order to work on the approximately linear part of the valve characteristic. By using a suitable cam between the servo-motor and the valve the margin can be reduced to, say, 10 per cent of $H_1(1 + {}^{S}/_{s})$, where H_1 is the maximum tidal range in the model. The power required becomes smaller as ${}^{S}/_{s}$ is reduced—that is, as the floor area of the box is increased.

Now considering the efficiency of the "pneumatic pump." The air horsepower of the fan is proportional to $Q_B \cdot h_A$, i.e., the area of the rectangle *abhf*, and the brake horsepower input to the fan is proportional to

$$\frac{Q_B h_A}{\eta f}$$

where ηf = fan efficiency.

Thus the overall efficiency of the "pneumatic pump" system

$$\eta = \frac{Q_c}{Q_B} \cdot \frac{h_B}{h_A} \eta f.$$

In order to obtain high values of η the ratios Q_c/Q_B and h_B/h_A should tend to unity, i.e., Q_D, the flow through the valve, must be small compared with Q_B, the flow through the fan, and $(h_A - h_B)$, the head lost in the ducting, must be as small as possible.

The maximum power is required at about half ebb tide, so that the maximum efficiency of the fan should occur at the corresponding

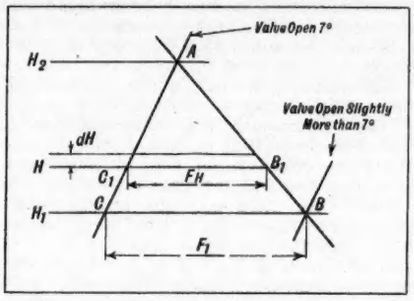


FIG. 16—CHARACTERISTICS IN REGION OF 7 DEG. VALVE OPENING

point on the *Qh* diagram. As this value of h_B is approximately half the maximum value, a fan with a steeply falling characteristic is required. The fan duty could be specified as approximately [1·25 Q_c max] c.f.m. at [0·75 $H_1(1 + {}^{S}/_{s})$]ft of water, with a shut valve head of [1·2$H_1(1 + {}^{S}/_{s})$]ft of water.

It is estimated that for the system actually in use on the Wyre model, the maximum brake horsepower required is nearly 2 h.p. and the maximum overall efficiency about 15 per cent.

If h_0 were made 0·1ft instead of 0·5ft, and a smaller butterfly valve used, it is estimated that the maximum efficiency would be about 40 per cent and the maximum brake horsepower required would be only ½ h.p.

Appendix III

Time Lag in Pneumatic System of Tide Generator

Fig. 16 represents a small portion of Fig. 11 at a valve opening of about 7 deg.

Now suppose the valve is set initially at slightly more than 7 deg. opening. After a steady state has been reached, point *B* will represent the conditions of operation of both fan and valve. Now let the valve be suddenly closed to 7 deg. Since the pressure in the tide box cannot change instantly point *B* will still represent the conditions for the fan, but point *C* will represent those for the valve. A short time later the suction head in the box will have increased and points *B'* and *C'* will represent conditions for fan and valve. After some considerable time, point *A* will represent the conditions of operation of both fan and valve. The change of head in the tide box is exponential with time, and the time constant is of the order of forty-five seconds. That is to say, if a sudden change of valve opening is made, it will be forty-five seconds before the pressure has changed 63 per cent of the final pressure change and about two and a quarter minutes before it is within 5 per cent of the final value. Furthermore, the "time constant" varies with the valve position, with adverse effects on the stability of the complete tide generator.

Derivation of Pressure/Time Relation.—Consider the small head change *dH* as shown in Fig. 16. If *A* is the floor area of the box the decrease of volume of air in the box is *AdH*. If F_H is the rate of flow of air out of the box the time taken for the change *dH* is given by

$$dt = \frac{A\,dH}{F_H}.$$

For the small total change of valve opening and pressure considered here, the characteristic curves for the fan and valve can be approximated by straight lines.

By similar triangles,

$$F_H = \frac{F_1(H_2 - H)}{H_2 - H_1}$$

$$\therefore \quad dt = \frac{A(H_2 - H_1)}{F_1} \cdot \frac{dH}{H_2 - H}$$

$$\frac{dH}{H - H_2} = -\frac{F_1}{A(H_2 - H_1)}dt$$

Integrating

$$\log_e (H - H_2) = -\frac{F_1}{A(H_2 - H_1)}t + C$$

$$H - H_2 = e^{-\frac{F_1}{A(H_2 - H_1)}t + C}$$

At $t = 0$, $H = H_1$,

$$\therefore \quad H_1 - H_2 = e^{C}$$

$$H = H_2 - (H_2 - H_1)e^{-\frac{F_1}{A(H_2 - H_1)}t}$$

which is of exponential form with time constant

$$T = \frac{A(H_2 - H_1)}{F_1} \text{ min.}$$

For the Wyre model, $A = 200$ square feet.

The "time constant" at various valve openings is given in the following table:—

Valve opening	$F_1/(H_2 - H_1)$ cu ft/min/ft	T sec
0	350	34
3 deg.	275	44
7 deg.	273	44
10 deg.	295	40½
16 deg.	465	26
22 deg.	940	13

With the modified fan and valve as suggested in Appendix II, the corresponding figures are:

Valve opening	$F_1/(H_2 - H_1)$ cu ft/min/ft	T sec
0	306	39
3 deg.	262	46
7 deg.	192	62½
10 deg.	188	64
16 deg.	280	43
22 deg.	583	20½

Oil Pollution

THE question of combating oil pollution was first considered in 1922, when the Oil in Navigable Waters Act was passed; this prohibited the discharge of oil within the territorial waters of Great Britain and Northern Ireland. British Shipowners examined the problem again two years later, and in 1926 a draft Convention was drawn up in Washington which provided for the prohibition of the discharge of oil in zones extending up to 50 miles, and in some instances, up to 150 miles, from the coast. Although never ratified by the Governments concerned, British shipowners have incorporated the 50 mile limit for the discharge of oil in the standing instructions to shipmasters. Up to the end of the war, most of this country's oil imports consisted of refined oil, but post-war developments, namely the enormous expansion of the home refining capacity, have completely changed the pattern of the oil trade. In 1938, crude oil formed one-fifth of the total petroleum oils imported, the proportion was one-third in 1949, and is now two-thirds. Since the imports of oil have doubled during the period, the quantity of crude oil is about six times the pre-war figure. Much is known on certain aspects of oil pollution, but little knowledge exists on the behaviour and capacity to persist under various weather conditions, of oil deposited at sea. To gain more knowledge on these matters is the object of British shipowners and as part of the research programme, three tanker companies have planned something in the nature of a Kon-Tiki experiment. Observers during the next two months will follow the drift of crude and fuel oil discharged into the sea during tank cleaning operations, determine the rate and direction of flow, and at intervals samples of oil will be analysed to establish the consistency. It is hoped that the data collected from the experiment will help towards the solution of this problem of oil pollution.

Indian Standards Institution

(*By our Indian Correspondent*)

With the inauguration on April 24, 1952, of the Building Division Council by the Union Deputy Minister for Commerce and Industry, the Indian Standards Institution fulfils one of the chief objects for its establishment as set out in the Government Resolution of September 3, 1946. Here we review the progress of the Institution since its inception in 1947, and discuss its activities in relation to the development of Indian industry during that period.

STANDARDISATION progress in India can be traced back to the appointment of an Inspector of Local Manufactures in 1909 by the Railway Board. This officer was required to inspect materials ordered from firms in the Calcutta area and was appointed to encourage the purchase by railways of products of local industries which conformed to railway specifications. The next important stage was the setting up of the Metallurgical Inspectorate for the inspection of a 20,000-ton supply yearly of rails and fishplates which the newly started Tata Iron and Steel Company had contracted for five years. This inspection and testing organisation laid the foundation of group standardisation in India taken up later on by other similar organisations like the Central Standards Office of the Railway Board, the Directorate of Technical Development, Army Headquarters, the Geological Survey of India, the Directorate-General of Supply and Disposals, the Central Board of Irrigation and Power, &c.

With the progress of industrial development, it was natural for the industries of the country and the Government to feel the need for establishing a national standardising body. A proposal for setting up such a body was sponsored at the twelfth Industries Conference at Lucknow (U.P.) in December, 1940. The Industrial Research Planning Committee also remarked in its report published in February, 1945, that the formulation of Indian Standard Specifications was an "essential preliminary to the maximum use of India's resources for the industrial development of the country." The Committee recommended that for "framing Indian Standard Specifications steps should be taken as early as possible for the establishment of a Board of Standards in this country." The war, however, delayed its establishment till 1946, when on September 3rd the Government passed a resolution in the Assembly setting up the Indian Standards Institution (I.S.I.) with, *inter alia*, the following objects :— To prepare and promote the general adoption of standards on national and international basis; to promote standardisation, quality control and simplification in industry; to provide for registration of standardisation marks; to provide or arrange facilities for the examination and testing of materials, commodities, &c.

Three months later, in January, 1947, the General Council of the Institution held its first meeting and the appointment of its present director was made in June that year.

Organisation

According to its constitution the affairs of I.S.I. are directed and managed by an executive committee. The general council, which appoints this committee, is presided over by the Union Minister for Commerce and Industry, and its members are representative of various other ministries, national and state, and of such national institutions as the All-India Manufacturers' Organisation, the Federation of Indian Chambers of Commerce, the National Institute of Sciences and the Institution of Engineers. The technical work of the Institution is distributed among the divisional councils, four of which have now been set up and are functioning, namely, Textile Division Council, set up in July, 1947; Engineering Division Council (November, 1947); Chemical Division Council (September, 1948); and Building Division Council (April, 1952). For preparing a particular standard or group of standards, the division council appoints a sectional committee which, in its turn, may appoint sub-committees and panels among its own members and others, if necessary. The total membership of these committees is about 2500 and there are about 260 odd committees at work.

The initial proposal for the establishment of a standard can be made by any member of the Institution or any authoritative body. The division council concerned then undertakes the investigation and, in consultation with producer and consumer interests, decides whether the need for the standardisation proposed actually exists. If the need is established and the executive committee approves, the division council concerned refers the work to an appropriate sectional committee, which, either itself or through the sub-committee, undertakes the preparation of a preliminary draft. The draft standard when prepared is issued in wide circulation for technical comments to all interested members of the Institution and other interests in the country and overseas. Generally, not less than three months are allowed for the collection of these comments, which are again considered by the sectional committee for incorporation in the draft. The final draft thus prepared is submitted to the division council concerned for endorsement and the executive committee for adoption, and is then published. On March 31, 1951, 179 standards had been published, thirty-eight were in the press, fifty-nine were finalised and about to go to press, ninety-eight standards were in circulation for eliciting comments, and 240 were in other stages of preparation.

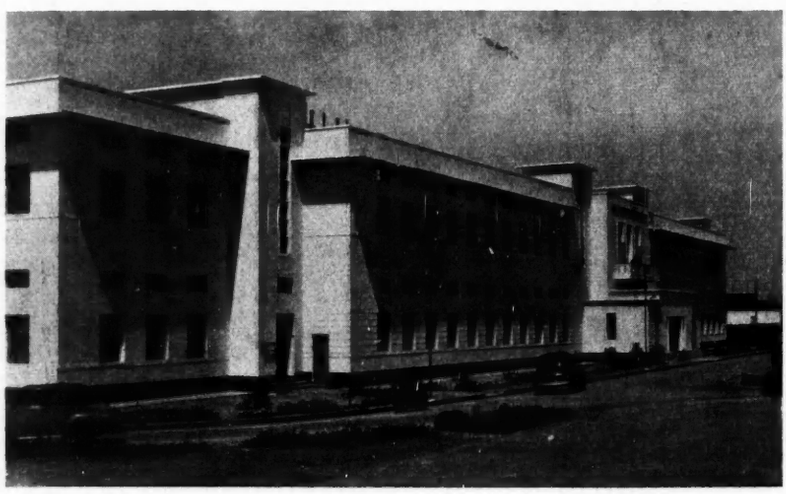
The Institution receives a grant of Rs. 220,000 (£16,500) from the Government, and last year collected about Rs. 186,000 (£14,000) from its members and subscribers. The sales proceeds from I.S.I. publications are comparatively low and amounted to about Rs. 20,000 (£1500) last year. Its annual budget is just under Rs. 500,000 (£37,500). The finances, according to the director, are wholly inadequate, and plans for expansion are consequently being held up.

The range of standards hitherto published is limited to raw, semi-finished and other materials figuring in India's export trade. With the establishment of the Building Division Council some finished goods such as sanitary ware, structural steel sections, &c., may enter the standards list. The I.S.I. has no laboratory of its own, but can and does draw upon the various state national laboratories of the Department of Scientific and Industrial Research, and also private laboratories and test houses of large manufacturing corporations. The top floor of the building illustrated herewith (the Shri Ram Institute for Industrial Research, Delhi) houses the Indian Standards Institution.

Implementation

As Indian standards are now being issued in increasing numbers, the question of their widespread implementation is assuming increasing importance. As stated in the fourth annual report (March, 1951), "the Institution, being a democratic body operating in a democratic country, can hardly at this stage envisage a compulsory enforcement of standards in any section of the industry." Nevertheless, there are some sections of industry which have from time to time advocated that all Indian Standards should be made mandatory by law. The Union Government itself has, from time to time, referred to the desirability of evolving a general policy in respect of the use of Indian Standards to guide the various purchasing and procuring agencies of the Government. In this respect, the passing of the I.S.I. (Certification Marks) Bill by Parliament last March is a step forward and merits attention.

Of late, India's export trade has been growing both in volume and variety. The Export Promotion Committee, 1949, had recommended that standards which "facilitate the transaction of business by enabling quotations to be made with reference to them, provided they are well understood by the buyer and the seller, should be prescribed as a means of reference," and "the quality of packing of commodities like tea and cotton piece goods should be standardised and adherence to these standards should be enforced." Unfortunately, imperfect understanding of trade usages in the past has sometimes led to complaints from overseas buyers to which the attention of the Government of India has been drawn by the Trade Commissioners abroad. It was natural, therefore, that I.S.I. should concentrate on such goods and articles as entered the export trade: for example, plywood tea chests, grading of wool for export, methods for grading processed mica, classification of processed muscovite mica shellac, shellac and dry bleached lac, codes for seaworthy packaging of woollen and cotton textiles, grading of raw jute (*kutcha* and *pukka* assortments), &c. With the passage of the I.S.I. (Certification Marks) Bill, statutory authority is conferred on the I.S.I. to establish certification marks and to issue licences to



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manufacturers for affixing them on their goods produced in conformity with Indian standards.

Weights and Measures

In 1949, the Government of India set up in the Ministry of Industry and Supplies a special committee in concurrence with I.S.I., under the chairmanship of the Director of Industry and Supplies, to consider the question of standardisation of weights and measures. It issued a questionnaire, examined the question at length and embodied its recommendations in a report forwarded to the Government with the endorsement of the general council of the I.S.I. The unanimous recommendation of the committee was that the metric system should be adopted, the change-over to be completed in three stages extending over a period of fifteen years. After that period, the only system accorded legal recognition should be the metric system. In the early stages of the change-over, decimal currency is also recommended.

The Government, however, has not taken any decision in the matter, and an inter-departmental committee specially appointed by the Ministry to work out the necessary details for the introduction of the scheme has not so far issued any report. Meanwhile, anxious inquiries are being received by the I.S.I. from important interests in the country. The planning commission, which is usually regarded as the final authority in such matters, has not given any effective lead in its draft five-year plan published last July. "The sectional committees of the I.S.I.," says the annual report (1951) "have often experienced difficulties due to the absence of a clear directive in this respect, and there are indications that many development plans, large and small, are dependent on the Government's attitude in this matter. Only recently, a reference was made by Tata Industries, Ltd., who wanted to know if the Government had accepted the recommendation, for in that case its factories would have to initiate changes in drawing and design office practice and also take note of it before importing any new plant or machinery for future expansion."

International Co-operation

The I.S.I. is a member of the International Organisation for Standardisation (I.S.O.). It participates in the work of twenty-nine technical committees and is entrusted with the secretariats of two technical committees for mica and shellac. India is also a member of the I.S.O. council to which it was elected for the first time in 1946 for three years. In 1949, the Director of I.S.I. was elected as the Vice-President of the I.S.O. The Indian Standards Institution maintains close relations with the national standard bodies of the Commonwealth and other foreign countries for whom it acts on a reciprocal basis as an agent for their standards, handbooks and similar publications. A representative of the I.S.I. attended the jubilee celebrations of the British Standards Institution held last year during the Festival of Britain.

American Engineering News

(By our American Correspondent)

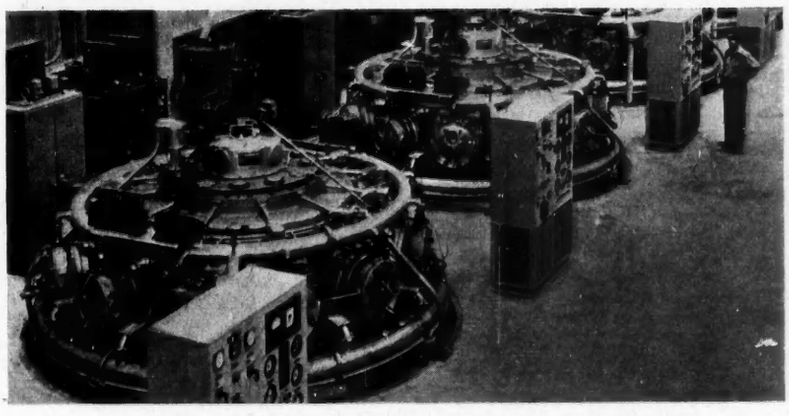
Addition to the Central Valley Project, California

A report by the U.S. Bureau of Reclamation recommending the addition of a Sacramento canals unit to the Central Valley project to provide irrigation water for 205,000 acres of land along the Sacramento River in the Glenn, Tehama, Colusa and Butte Counties of California has been sent to Federal agencies and State officials for review and comment. Water for the Sacramento canals unit would be supplied in part by diversion of surplus water from the Trinity River in California. Briefly, the plan of development involves the distribution of approximately 660,000 acre-feet of water annually through three main canals diverting from the Sacramento River. On the west side of the valley, the Corning Canal would begin near Red Bluff and extend southerly a distance of about 25 miles to serve lands in southern Tehama County. Water for this canal would be lifted 55ft from the Sacramento River by an electrically powered pumping plant. Also on the west side of the valley, a gravity conduit would be constructed, extending from Red Bluff to a point near the Colusa–Yolo County line, a distance of about 120 miles. The Redbank diversion dam, 25ft high and about 750ft long, would be constructed across the Sacramento River near Red Bluff to divert water into the canal. On the east side of the valley, the Chico Canal would serve lands in the vicinity of Chico by a 30ft pumping plant diversion near Vina, extending about 20 miles to Butte Creek near Durham. In addition to the main canals, distribution and drainage systems will be required to deliver the water from the canals to the farm headgates and to carry unconsumed water away. The total construction cost of the three canals, including the diversion dam and pumping stations on the river, is estimated at 54,510,000 dollars. The cost of the distribution systems is estimated at 60,155,000 dollars, making a total construction cost of 114,665,000 dollars. The construction costs would be repaid to the U.S. Federal Government by payments from water users and from the sale of hydro-electric power generated on the multiple-purpose Central Valley project, of which the Sacramento canals unit would be an operational and financial part. The report points out that the proposed new works are economically justified, producing benefits which exceed the costs in a ratio of more than 2 to 1. Water for the Sacramento canals unit can be provided for the next few years from the reservoir behind Shasta dam, the key control structure of the Central Valley project, and by exchange from the Folsom reservoir, which is now under construction by the U.S. Army Corps of Engineers.

The Point Comfort Aluminium Reduction Works, Texas

An increase in aluminium smelting capacity of 70 per cent has now been made possible at the Point Comfort Reduction Works in Texas of the Aluminum Company of America by an addition to its power generating facilities. The original generating facilities were described in an article on the Point Comfort Works which appeared in The Engineer of September 22, 1950. The power station at Point Comfort is now believed to be the world's largest internal combustion engine generating plant and has a total engine rating of approximately 350,000 h.p. The increase in available power will give the works an annual aluminium producing capacity of about 80,000 tons. It may be recalled that the Point Comfort Works was the first new aluminium smelting plant to be built in the United States after the war and the first in the state of Texas. The original power plant included 120 engine generator units, forty of them being housed in each of three buildings. To increase the power output, seventy-four new units have now been installed in two additional buildings. All 194 engines were built by the Nordberg Manufacturing Company, of Milwaukee, Wisconsin, and are of two-cycle, radial design, incorporating a dual spark ignition system. The engines have a 14in bore and a 16in stroke. Several of the recently installed engines are shown in the accompanying engraving.

Although the seventy-four new engines are similar in general design and appearance to the 120 original ones, there are important differences between the two. The new engines have twelve cylinders instead of eleven, and since the cylinders are of the same size the later model develops about 9 per cent more power. Furthermore, a stabilising mechanism is employed in the new engine to permit the master crankpin bearing assembly to gyrate and yet to prevent it from rotating in response to the torque from the connecting-rods. This was accomplished in the original eleven-cylinder engine by a planetary gearing system. In the new engines, however, a simple crank mechanism operating between two connecting-rods and their knuckle pins is substituted for the gearing. The relatively small torque tending to rotate the master crankpin bearing assembly is absorbed by small reactions on two of the pistons. Although the same impulse generator is used for ignition purposes on both engine models, it is combined with the distributor as a single unit in the new model, instead of being driven separately. Except for these changes the two engines are essentially the same. In both models, intake and exhaust are timed by the pistons as they uncover ports in the cylinder walls. Natural gas is admitted to the engines by cage-mounted gas valves. The valves are operated by a cam on the crankshaft and are situated so that the gas is admitted into the path of the incoming scavenging air, assuring thorough mixing and efficient, economical burning of fuel. A valve inserted in the gas line and controlled by a hydraulic governor varies the amount of gas delivered to the cylinders according to the load on the engine. Seventy-four generators made by the Elliott Company, of Jeannette, Pennsylvania, are situated at the lower level of the new power stations and are joined to the engines by direct coupling. Each engine generator unit, with its auxiliaries, operates independently, producing 1100kV at 667V d.c. and 135kVA, at 425V, 24 c/s a.c. The a.c. power is used for driving such auxiliaries as the scavenging air blower, the oil and water pumps, and radiator cooling and generator ventilating fans. This arrangement eliminates the need for a common auxiliary power system and the possibility of a total station interruption. As in the original plant, each engine generator unit has its own control panel. In general, the basic engine shutdown and protective features, which proved so successful in the original installation, have been employed in the two new stations with only minor changes. The addition of the seventy-four engines will raise the daily consumption of natural gas at Point Comfort from 30,000,000 cubic feet to 50,000,000 cubic feet.



Engine-Generator Units at Point Comfort Works

Strengthening American "T-2" Tankers

As a result of the recent serious casualties which occurred in two American "T-2" class

tankers, the 16,500-ton "Fort Mercer" and the 10,448-ton "Pendleton," the American Bureau of Shipping has decided that it is necessary that measures be taken to provide additional safeguards in this class of vessel against a repetition of such failures resulting in a complete severance of the hulls. The Committee on Naval Architecture and, subsequently, the Technical Committee of the Bureau have given careful consideration to the circumstances surrounding the latest failures. They have made a review of all available information obtained from the records of ships in service, from previous casualties, and also from the large amount of research work which has been carried on continuously in connection with the special problems attendant upon welded construction. As a result of these deliberations the American Bureau of Shipping has sent the following instructions to the owners of approximately a hundred "T-2" tankers which fall under the jurisdiction of the Bureau: "It has been decided that the 'T-2' type tankers are to be provided with at least eight riveted crack arresters in the girth of the ship, spaced with due regard for the loss of intact plating resulting from a crack extending between any of the arresters; that the attachments of the bilge keels to the shell are to be riveted, and that in conjunction with these alterations there is to be provided such additional effective longitudinal material as will result in a general increase of 15 per cent in the longitudinal strength of the vessel as measured by the section modulus of the 'midship section when compared to the modulus of the original basic design. The longitudinal extent of the alterations should be approximately the same as the longitudinal extent of the present riveted arresters, due regard being given to avoiding an abrupt termination of the additional material. A slot and riveted strap, a heavy internal girder connected to the plating by riveting, or a doubling plate attached to the plating by riveting is to be considered as a crack arrester. During the wartime tanker construction programme there were incorporated into the hulls of approximately the last two-thirds of these vessels heavy I-beam section girders under the deck. These girders can be counted as additional effective material over and above the original design, provided they are connected to the deck. Where the connections are made by riveting, these girders can be included as crack arresters. In view of the close proximity of the bilge keels to the existing riveted crack arresters it is not intended that the riveted bilge keels will be included as one of the additional arresters required. The committees also recognise the fact that in the 'T-2' tankers the ratio of the cubic capacity of the cargo tanks to the available deadweight for cargo is such that when carrying all but the lightest of petroleum products it is necessary that one or more tanks be empty or only partially filled. This excess cubic capacity permits some variations in the arrangements of loading at proper trim, which in many cases can be used to good advantage in reducing the sagging moments resulting in high-tension stresses in the bottom structure. Similarly, the arrangements for ballasting may be varied to a considerable degree and there are many combinations which could be used to good advantage in reducing the stresses in the structure. The Bureau is collaborating with the U.S. Coast Guard in the preparation of a manual on loading arrangements applicable to these vessels which will be issued as a guide to owners and operators to assist in the discharge of their responsibilities for judicious loading. A great many of these vessels have had previous alterations, some of which have resulted in the provision of additional longitudinal material of varying degree which can be included in assessing the required added strength and also which, in some cases, can by simple alterations be adapted into an arrangement which can be considered to be the equivalent of a crack arrester. The service records of these vessels indicate that serious failures occur exclusively under the conditions of low temperature and heavy seas, such as are encountered only in the winter season. However, it is felt desirable that the foregoing alterations be taken in hand at the first convenient opportunity."

Incidentally, it is of interest to note that the tanker "Fort Mercer" will return to sea again as a larger ship in due course. The vessel is to be fitted with a new forward section, longer than that which was severed off the New England coast. Her stern section, upon which part of her crew was able to return to New York, has now been towed to Galveston, Texas. A contract for the rehabilitation of the "Fort Mercer" has been awarded to the Todd Shipyards Corporation by her owners, the Trinidad Corporation. No cost details of the project have been made public, but it is believed the work will entail an expenditure in excess of 2,000,000 dollars. The new section is to be constructed by the Houston Division of the Todd Corporation and then floated to the Galveston yard for joining to the after section. The new part of the vessel will be 278ft long, adding 41ft to the ship's original length. The result will give the vessel an additional tank, raising her cargo capacity another 2000 tons and giving her a new deadweight of about 18,500 tons.

Oil Refinery in Antwerp

On June 23rd, Monsieur J. Van Houtte, Prime Minister of Belgium, opened officially the new oil refinery of the Société Industrielle Belge des Pétroles (S.I.B.P.) in the presence of numerous prominent persons, including Sir Christopher Warner, H.M. Ambassador in Belgium, and Sir William Fraser, Chairman of the Anglo-Iranian Oil Company (A.I.O.C.)

The S.I.B.P. Company was founded in 1949 by the Petrofina Company and the Anglo-Iranian Oil Company, each company having a 50 per cent share. The new oil refinery, the most important at present in Belgium, is situated on the right bank of the Scheldt River (Escaut), South of the Kruisschans Lock. The annual output, originally 1·4 million tons, is at present of 1·8 million tons. In future, however, this figure will be increased up to 3 million tons per annum. The refinery covers about 190 acres, and cost £9·4 million. To establish the plant level above the high water of the river, it was necessary to raise the level by 16½ft, which required about 6½ million cubic yards of earth-filling. Crude oil, coming from the Middle East, is unloaded at the jetty of the new oil harbour, and then put into storage reservoirs. There are nine tanks, 142ft in diameter, with an overall storage capacity of 245,000 cubic yards.

South African Engineering News

(By our South African Correspondent)

Wheel and Axle Manufacture: A New Project for South Africa

As a result of recent negotiations by the English Steel Corporation and its subsidiary, Taylor Brothers and Co., it is expected that the corporation's recently established undertaking, Steel Wheel and Axle (South Africa), Pty., will, in the not too distant future, commence manufacturing in this country the rolling stock components now being turned out by Taylor Brothers in England. Local manufacture in South Africa of the Taylor components would entail bringing out to this country a complete production unit. Initially, wheels and other items would be imported in semi-processed form and finished in the South African factory, but later it should be possible to obtain suitable hard steel from sources within the Union, so that the complete manufacture of wheels, tyres and axles might be undertaken locally.

Iron Deposits in Northern Rhodesia

Large deposits of high-grade iron ore have been located in the Lusaka area. An initial production of 20,000 tons of pig iron a year is envisaged by the consulting engineers now investigating the iron ore outcrops, which will go a long way toward easing the serious shortage of pig iron in both Rhodesias.

French Engineering News

(By our French Correspondent)

Morocco has formulated a new four-year development plan which should come into effect this year and last until 1956. Great stress will be placed on the import and manufacture of agricultural machinery, as well as on irrigation work. The last plan came to an end in June of this year.

The airport at Camp Cazes in Morocco is to be rebuilt to enable the runway to take the new 75-ton Armagnac aircraft which will shortly be used on the North African route. Meanwhile, the aircraft will use an American runway at Nouaceur. The runway at Camp Cazes is long enough, but the weight of the plane is such that a heavier construction is necessary.

* * *

The last section of the Paris–Lyon electrified line has now been inaugurated. This section is 512km long, and it brings the full length of the electrified lines on the S.N.C.F. up to 3514km, out of a total of 40,727km.

The average speed for electric traction on this line is 120km per hour, with a top speed of 140km.

* * *

A new thermal power station at Dechy, in the north of France, has come into operation. The "unit system" has been used in its design; the furnaces were designed to burn very low grade fuel, and special attention has been paid to the design so as to reduce the manpower required for its operation to a minimum. This 120MW installation brings the total power for the Nord and Pas de Calais "bassin" up to 560MW; production has been stepped up from 2 milliard kWh in 1944 to 4 milliard. Other installations are being designed or are under construction. Next month a new 40MW plant at Thiers will come into use and at Auchel, a 60MW plant will be ready in two years, bringing the Auchel power station up to a capacity of 400MW.

* * *

A note on the electrification of the Valencienne-Thionville line has been published by the French Railways. This states that 50 c/s 25kV alternating current will be used, thus bringing about substantial economies. The existing line will not be changed but two level crossings will be superseded. Work on this line is likely to be held up a little through lack of credits.

* * *

The Chastang dam and hydro-electric power station has been officially inaugurated and has been highly praised in the French press. The head of the scheme is 85m, and the turbines normally take a flow of 100 cubic metres per second. Work at Chastang started in 1942; it is the last of a series of four important hydro-electric developments in the Dordogne. Upstream, the dams and associated power stations of Bort, Mareges and Aigle are situated. There are thus four reservoirs on 120 kilometres of the river, giving a storage of 830 million cubic metres. The energy generated at Chastang will amount to some 540 million kWh per year.

* * *

Over the past two years the Houilleres de la Loire has had under construction a new coking plant. It was completed in June and is the most up-to-date plant in the country. Production is estimated at 300,000 cubic metres of gas at 4200 calories. The gas will be purchased by Gaz de France. Work is now going ahead on two mains which will carry the gas to a central distribution point, from where it will branch into mains leading to Lyon, Clermont Ferrand and Vichy.

* * *

Railways on the Reunion Islands are to be modernised and rebuilt. Over the next five years all steam-powered locomotives will be replaced by diesel locomotives or railcars. Shunting engines will also be bought for the islands; they will be of 400 h.p. and 300 h.p., and will haul trains serving the sugar factories.

The railway workshops are also to be rebuilt. Two overhead travelling cranes of 20 tons capacity will be amongst the new plant installed. The complete modernisation will cost about 276,000,000 francs.

Industrial and Labour Notes

An Industrial Research Fellowship

It is announced that a fellowship worth £1000 (Australian) is being offered to students in any branch of industrial research by the British Memorial Fund, which has been established by public subscription, in Victoria, Australia. This fellowship, it is stated, is an expression of loyalty, gratitude and affection to the British people in recognition of "their role in saving civilisation in the second world war."

The fellowship is open to any well-qualified students—men and women between the ages of twenty-five and thirty-five—in industrial management or some branch of social science; to office bearers in any chamber of manufacturers, employers' federation, or junior chamber of commerce; to trade union officials, and executives in industrial undertakings, or to any other person with extensive experience in industrial affairs or general administration. Applicants, who must be of British stock, must have been ten years resident in the United Kingdom. The fellowship provides for ten months' study in Victoria for the selected candidate, and covers all travelling and living expenses during that period. Research will be encouraged into any aspect of Australian industrial life with special emphasis on Anglo-Australian relations generally and trade relations in particular. Applications will be received during the next four weeks. They will then be studied by a selection committee which will make three recommendations, in order of preference, to the fund organisers in Melbourne, where the final choice will be made.

Simultaneously with the industrial research fellowship, fellowships are being offered by the Fund for Natural Science, Virology and Agriculture, the same conditions applying. Full details of all the fellowships can be obtained from Sir John Lienhop, chairman of the London selection committee, Victoria House, Strand, London, W.C.2.

The Electronics Industry in Scotland

Answering a parliamentary question, a few days ago, about the progress of the electronics industry in Scotland, the Minister of Supply, Mr. Duncan Sandys, said that a scheme had been worked out for a new laboratory block to be erected adjacent to the premises of Ferranti, Ltd., in Edinburgh, at a cost of £513,000. The provision of a new building and ancillary services to a value of £205,000 had been authorised and architects' drawings were being prepared, and machine tools to the value of £102,000 had been allocated to Ferranti, Ltd., from the Ministry's stocks. The Minister added that Ferranti, Ltd., was in communication with a number of firms which might be suitable associates and that the employees of one firm had already begun work in the Ferranti premises. Furthermore, Mr. Sandys said, four firms were doing electronic work in their own premises on sub-contract from Ferranti, Ltd., and under its guidance.

Wages and Prices

Writing in *Man and Metal*, the monthly journal of the Iron and Steel Trades Confederation, Mr. Lincoln Evans, the general secretary, makes several observations on the subject of wages and prices. He says that with prices rising rapidly, as they have over the last twelve months, it is unreasonable to expect that wages can remain stationary, for "when the pressure of higher prices is felt, the demand for increased wages inescapably follows."

Unfortunately, Mr. Evans continues, this country's economy is so delicately balanced that any sharp variation in world trade or price levels can set it shaking. When that happens, a new series of general wage claims start up which, although inevitable, simply aggravate the position. As a cure, Mr. Evans comments, "we frequently get the demand that there should be some central authority set up to exercise control over wage claims, and to assess the relative merits of each." But, Mr. Evans claims, those who advocate a centrally-controlled wages policy ignore the varied and complex wage structures that apply in the different industries, and fail to take into account the democratic character of the processes by which the unions formulate wage claims, or the collective bargaining machinery through which they have to be argued out. If such a policy was adopted, Mr. Evans says, it is difficult to see how there could be avoided a gradual paralysis overtaking the whole system of voluntary collective bargaining.

Mr. Evans goes on to say that the responsibility of the trade unions in the circumstances of to-day is not lessened but considerably increased, and that ought to be shown by bringing the wage claims that are being pursued into some king of equality with the actual rise in the cost of living. Anything very much more than that, according to Mr. Evans, will simply mean that the wage-price spiral will get a sharper twist upward than the circumstances warrant.

Distribution of Primary Copper

The copper, lead, and zinc committee of the International Materials Conference has recently announced that its member-governments have accepted its proposals for the allocation of copper in the third quarter of this year. Twelve countries—Australia, Belgium, Canada, Chile, France, the Federal Republic of Germany, Italy, Mexico, Norway, Peru, the United Kingdom and the U.S.A.—are represented on the committee.

The committee has recommended a plan of distribution of 744,290 metric tons of copper in the current quarter, compared with 723,680 metric tons last quarter. The amount allocated to the United Kingdom is 100,300 metric tons, and to the U.S.A. 368,100 metric tons, the latter figure including provision for strategic stockpiling. The committee says that, in making the allocations, direct defence needs have been given priority. As for the last quarter, primary copper only is included in the allocations. While semi-fabricated products have not been allocated, all exporting countries are asked to continue to maintain their exports of such semis at a level commensurate with their allocation of primary metal for civilian consumption, in accordance with normal patterns of trade. All countries have also been asked to continue measures for conservation and end-use control.

In addition to the twelve countries represented on the committee, the plan of distribution has been sent to twenty-seven other countries for which copper allocations have been recommended.

Britain's Oversees Trade

In its report giving the final figures for the country's overseas trade in June the Board of Trade reviews the trade during the first half of 1952. During this period the adverse trade balance amounted to £470 million—£186 million less than the figure for the second half of 1951, and £82 million less than the first half of that year. It is pointed out that the principal factor leading to this improvement, compared with the previous half year, was an 8 per cent decrease in imports—from £2058 million to £1902 million—which included a significant reduction of some 14 per cent in imports from the non-sterling area.

The total value of United Kingdom exports in the first half of this year at £1347 million showed but little change from the value in the second half of 1951—£1340 million—but this included a reduction of 13 per cent in value of exports between the first and second quarters of the year. It is stated that the restrictions placed on imports by Commonwealth countries played a large part in this reduction in exports, although the occurrence of both the Easter and the Whitsun holidays in the second quarter meant that a drop of 5 per cent might have been expected.

In dealing with exports, it is pointed out that the exports of metals increased by £27 million, or 24 per cent, during the first six months of 1952, as compared with the second half of 1951. The value of machinery exported exceeded that exported in the second half of 1951 by 13 per cent; part of this increase in value was due to higher prices, but there were substantial increases in quantity for several of the principal classes of machinery.

Apart from metals and machinery, the general trend in imports of manufactured goods was downwards, the total value for the first half of 1952 being £455·6 million, as compared with £481·4 million in the second half of last year. Machinery imports totalled £52·9 million, as compared with £30·9 million in the second half of 1951 and £44·6 million for the whole of 1950. Imports of iron and steel manufactures increased even greater to £61·3 million, as compared with £27·6 million in the second half of 1951.

A Sales Company for Steel Products

A joint announcement by Richard Thomas and Baldwins, Ltd., and the Steel Company of Wales, Ltd., states that a new company, R.T.S.C. Home Sales, Ltd., is being formed, with a registered office at 47, Park Street, London, W.1. This company is being formed for the purpose of effecting and carrying through as principals (not as agents) sales in all parts of the United Kingdom and Northern Ireland, the Channel Islands and the Isle of Man, of the flat rolled steel products manufactured by Richard Thomas and Baldwins, Ltd., and the Steel Company of Wales, Ltd. The first directors of the company will be Mr. H. F. Spencer, the assistant managing director of Richard Thomas and Baldwins, Ltd., and Mr. E. Julian Pods, the managing director of the Steel Company of Wales, Ltd., both of whom are directors of R.T.S.C. Exports, Ltd., which was formed a year ago to co-ordinate and stimulate sales of the companies' products throughout the world. The new company will not become active until near the end of this year or early in 1953, and customers are being requested to continue their present contacts with the individual companies until advised to the contrary.

The Economic Situation in Sweden

The quarterly review issued by the statistical department of the Skandinaviska Banken A.G., dealing with the economic situation in Sweden during the second quarter of 1952, says that prospects are favourable in the iron mining and metal industries, including the engineering industry. A very pronounced demand exists for iron ore, and the large exporters of engineering products have maintained their position well. Home market demands are still good, but there have been indications of increasing difficulties in the export markets. It is pointed out, however, that the industries concerned can face a possibly diminishing demand with an order stock equivalent to one-and-a-third years' production. During the first quarter of 1952, the production of pig iron amounted to 261,000 tons—26 per cent more than the corresponding period of 1951. For other iron production, the average exceeded last year's by 13 per cent, and there was an increase of 10 per cent in steel production. A large expansion scheme at the state-owned Norrbottens Järnverk will enable an increase in pig iron output of 200,000 tons annually. Increased plant capacity at the Domnarvets Jernverk will give an increased production of from 200,000 to 400,000 tons a year of rolled iron.

Notes and Memoranda

Rail and Road

ROAD DEVELOPMENTS IN FIJI.—A report from the Colonial Office says that Fiji's post-war road development programme, which was held up pending the receipt of heavy equipment, is now making steady progress. It has taken nearly two years to assemble the heavy road-making equipment required, to recruit technical staff, to train local men in the use of the new equipment, and to establish depots with housing, workshops and offices. A survey party consisting of a senior engineer and two assistants began work on locating a new road in the Sigatoka Valley in June last year, and completed its survey at the end of February. The party then moved to the Labasa area. The construction of the Sigatoka Valley road began in September, 1951, and nearly 6 miles of road have so far been completed. At the end of 1951, work began on the Nakama road, near Labasa. This gives access to the airstrip and will also open up a new sugar growing area. In addition to road-building, the Public Works Department has been working on airstrips to serve the people of Vanua Levu and Taveuni. The Labasa strip, 1100 yards long and 100 yards wide, was completed last year. The strips at Savusavu and Taveuni are now being surveyed and a start will be made on their construction in the next few months.

ROAD ACCIDENTS IN MAY, 1952.—The Ministry of Transport records that ninety-two fewer people were killed on the roads in May than in the same month last year, but that the number of those injured increased by 677. The total number of killed and injured was 19,018 (as compared with 18,433 in May, 1951) including 352 killed, 4452 seriously injured, and 14,214 slightly injured. Compared with May, 1951, the most disturbing feature was an increase of 940 in the casualties to pedal cyclists, which totalled 5312, but the number of cyclists killed, fifty-five, was, however, eleven less. Motor cyclist casualties increased by 293 to 3175, but in this group also deaths were fewer there being ninety, compared with 102. Casualties to adult pedestrians numbered 2264, of which seventy-three were fatal. Compared with May, 1951, the figures show a decrease of 197 in the total and of thirty-nine in those killed. There was, however, a small increase in casualties to child pedestrians. These numbered 2455, including fifty-eight killed, making a total for pedestrians of all ages, of 4719. Casualties to drivers, other than motor cyclists, fell by 164, to 1453, of which twenty-one were fatal. Figures for the first five months of the year show that there were 1875 fewer casualties to pedestrians than in the same period of 1951.

Air and Water

S.S. "FLANDRE."—The French liner "Flandre," built by Ateliers et Chantiers de France, Dunkirk, has returned to Havre after several days' sea trials, during which she exceeded a speed of 25 knots.

AMERICAN BUREAU OF SHIPPING.—The American Bureau of Shipping advises that as from July 1st, Mr. Dale A. Kroeger has been appointed Principal Surveyor for Great Britain, Ireland and Western Europe. He succeeds Mr. William H. Low, who has been in charge of the London office since its opening, and who is returning to the United States as Chief Surveyor-Operations.

COASTAL LIFE-SAVING SIGNALS.—The signals to be used by life-saving stations when communicating with ships in distress and also used in the reverse direction, set out in the regulations of the International Convention for Safety of Life at Sea, 1948, will come into force on November 19th this year. Poster C.G. 27, issued by the Board of Trade in 1925, will no longer be applicable, and it will be replaced by a new poster setting out the Convention signals. Copies are obtainable from any mercantile marine office.

HYDROGRAPHER'S REPORT.—The Hydrographer of the Navy, Rear-Admiral A. Day, has issued a report containing a summary of the surveys carried out last year by H.M. Naval Surveying Service, and some details of the work of the hydrographic department. Eight ships were employed during the year, four in home waters and four abroad. H.M.S. "Cook," a converted "Bay" class frigate, was commissioned early in the year and relieved H.M.S. "Seagull." H. M. Ships "Cook," "Franklin," "Scott" and "Sharpshooter," with the assistance of attached M.L.s, carried out surveys over a number of areas in home waters around the coast, many wrecks were swept for least depth and tidal stream observations made. H.M. Ships "Owen," "Dalrymple," "Dampier," and "Challenger" completed surveys in the Persian Gulf, off Zanzibar, at Hong Kong, along the west coast of Borneo, in the vicinity of Singapore and Penang, and in the Mediterranean. Oceanic cruises to obtain soundings and make magnetic observations were continued in the Pacific Ocean and examination of reported shoals was undertaken.

Miscellanea

ELECTRICAL INDUSTRIES BENEVOLENT ASSOCIATION.—Mr. R. H. M. Drake, chairman and managing director of Drake and Gorham, Ltd., has been elected president of the Electrical Industries Benevolent Association, in succession to Mr. C. R. King.

ERRATUM.—Our attention has been drawn to the fact that an error in the price of the British Scientific Instrument Research Association's publication M.9. occurred in our issue of July 18th, page 93, under Short Notices—"A Bibliographical Survey of Flow Through Orifices and Parallel-Throated Nozzles." The price should have read 32s. 6d.

KING'S COLLEGE LONDON ENGINEERS' ASSOCIATION.—We are informed that the King's College London Old Students' Association, Engineering Branch, will in future be known as the King's College London Engineers' Association. Mr. A. V. Driver is the honorary secretary of the Association, the headquarters of which are at King's College, Strand, London, W.C.2.

METAL PRICES.—The Minister of Supply has made an Order increasing the prices of secondary copper, brass, copper scrap, gilding metal scrap, brass scrap and cupro-nickel scrap to take account of the recent advance in the Ministry of Materials' selling price of virgin copper. The Order, which is entitled the Copper, Zinc, &c., Prices (No. 3) Order, 1952, came into force on July 16th.

RAIL TANK WAGONS.—Manchester Oil Refinery, Ltd., has recently taken delivery from Hurst, Nelson and Co., Ltd., of several new tank wagons. These are of all-welded construction, with the tank welded directly to its steel cradle, no tie lines or stay wires being required. Steam coils maintain the correct temperature for easy transfer of the oil, and side outlet pipes facilitate the coupling of connections. The capacity of each wagon is 14 tons, and the tare weight is 8 tons 19 cwt.

ALUMINIUM REFERENCE NUMBERS.—We have received from T.I. Aluminium, Ltd., a leaflet which sets forth the change in the company's alloy nomenclature. The new coding system, which comes into use on August 3rd, uses the prefix T.I. to indicate origin, and the first numeral indicates the alloy group according to the main chemical constituents, while the second and third numerals represent the alloy number. A table covers all alloys in general use and includes, in addition to the new numbers, old numbers and the corresponding B.S. and D.T.D. specifications.

STUDY OF ASH AND CLINKER.—A conference is being convened by the Institute of Fuel for a special study of ash and clinker in industry. It will be held at the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W.1, on Tuesday and Wednesday, October 28th and 29th, the sessions each day beginning at 10 a.m. and 2 p.m. Eleven papers are to be presented for discussion, dealing with industrial fuel burning plants of many kinds, and the effect upon their performance of ash and clinker from various fuels. Before the conference ends on Wednesday afternoon, October 29th, a summary of the proceedings will be presented by Dr. D. T. A. Townend.

INDUSTRIAL DRYING.—The value of efficient drying processes to industry has grown in recent years with the great need for fuel saving, and a book entitled *Bibliography of Industrial Drying* has been published by the Department of Scientific and Industrial Research. This bibliography covers the period 1924–50, and its 800 pages carry some 4500 entries. The first two sections of the work deal with principles, processes and equipment, and include a limited number of references on heat transfer and drying of gases. A further three sections cover the various drying methods that can be used in agriculture, in the food processing industry and in the drying of industrial materials. Each section is divided by sub-headings under which the references are listed alphabetically. This book can be obtained only from the Department of Scientific and Industrial Research, Technical Information and Documents Unit, Cunard Buildings, Regent Street, London, S.W.1, price £1 7s. 6d. (by post £1 8s. 7d.).

ALUMINIUM DATA.—High Duty Alloys, Ltd., Slough, has recently compiled and issued a new Hiduminium Technical Data Book. The data contained in the complete book is available in alternative forms, a second edition containing data information only, being primarily intended for use where light alloys are not used extensively, while the third edition consists of comparative tables. The complete book is presented in double binding form, and the initial pages set forth the characteristics of Hiduminium wrought and cast alloys. In the next seventy pages the physical and mechanical properties are detailed, together with heat treatment information, notes upon applications, and other typical values of the whole range of wrought and cast alloys. This is followed by more extensive general notes on mechanical properties with reference to fatigue strength, behaviour at elevated temperatures, welding and forming. Protection against corrosion is discussed, also anodising and painting, and there is a section dealing with cutting tool materials, including some recommendations for machining operations. The three forms of heat-treatment commonly applied to aluminium alloys are briefly outlined. Technical data tables form the second part of the book, and these list the principal mechanical properties required by current specifications. They are grouped against nominal compositions, while for convenience, the corresponding trades are included. The tables cover all the forms of aluminium and its alloys produced by the company, including sheet, plate, wire, extrusions, forgings and castings.

Personal and Business

MR. N. R. REANEY and Mr. P. P. C. Drabble have been appointed directors of Geo. Salter and Co., Ltd., West Bromwich.

MR. B. HAWLEY has been appointed a director of A. E. Walsh and Partners, Ltd., 92, New Cavendish Street, London, W.1.

MR. E. D. HART, M.A., A.M.I.E.E., has joined the equipment division of Mullard, Ltd., as head of the technical department.

MR. R. H. SENIOR, and Mr. A. R. Hughes have been elected directors of the Cunard Steamship Company, Ltd., and of Cunard White Star, Ltd.

A. A. JONES AND SHIPMAN, Ltd., announces that the telephone number of its London office, Murray House, 5, Vandon Street, Buckingham Gate, S.W.1. has been changed to Abbey 5908.

MR. R. B. SAWREY-COOKSON has relinquished his post as public relations officer of the British Road Federation to take up an appointment in the public relations department of the Esso Petroleum Company, Ltd.

MR. H. LESLIE BOWES, C.B.E., a director of the Pacific Steam Navigation Company, has been elected president of the Liverpool Shipping Staffs' Association, and Mr. W. Tapson, of the same company, has been elected chairman.

VICKERS-ARMSTRONGS, Ltd., announces that Mr. T. Gammon, M.I.Mech.E., manager of the Weybridge works, and Mr. W. D. Opher, M.I. Mech.E., works superintendent of the Crayford works, have been appointed directors.

NU-SWIFT, Ltd., Elland, Yorks, states that Mr. F. Graucob, managing director, has been elected chairman in succession to Mr. A. Harland, who has resigned owing to advancing years. Mr. Harland has become president of the company, Mr. E. E. C. Cawood, general manager, has been appointed technical director.

MR. P. V. HUNTER, C.B.E., M.I.E.E., is relinquishing, at his own request, on August 31st, his position as a deputy chairman of British Insulated Callender's Cables, Ltd. At the request of the company, he will continue to serve as a non-executive director, and will remain on the boards of several of the subsidiary companies.

CHAMBERLAIN INDUSTRIES, Ltd., Staffa Works, Leyton, E.10, states that Mr. H. G. H. Pritchett has been appointed general sales manger, and Mr. D. S. Jordan, deputy sales manager. The firm also announces that its activities in Scotland are being handled by Gerard Wakeham, Ltd., Carlton House, 26, Blythswood Square, Glasgow, C.2.

THE BRITISH BROADCASTING CORPORATION states that Mr. H. Bishop, F.C.G.I., M.I.Mech.E., M.I.E.E., has been appointed director of technical services in succession to Sir Noel Ashbridge, who is retiring. Mr. R. T. B. Wynn, M.I.E.E., succeeds Mr. Bishop as chief engineer, and Mr. F. C. McLean, M.I.E.E., becomes deputy chief engineer in place of Mr. Wynn.

British Patent Specifications

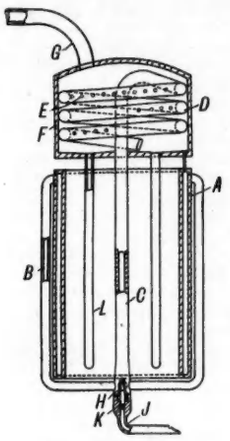
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

STEAM GENERATORS

674,991. September 22, 1949.—STEAM GENERATOR, Cecil Vance Bowles, of 52, Cleveden Drive, Glasgow, W.2.

This invention is designed to obviate the danger of overheating at high rates of expansion in a steam generator. In the drawing, *A* is a mercury container, annular in cross section, exposed to a source of radiant heat. *B* denotes tubes leading from the top of the container to the lower end of an axial vertical mixing tube *C*, which discharges at its upper end into a steam separator consisting of a coiled tube *D* with orifices *E*. The steam chamber *F* is provided with a steam outlet pipe *G*. The orifices are formed in the inner periphery of the coiled tube. H is a nozzle protruding into the tube *C* and connected to a water supply pipe *J*, a non-return valve *K* being interposed between the pipe and the nozzle. Return tubes *L* lead from the



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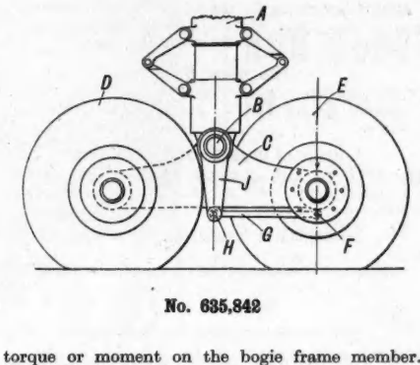
bottom of the steam chamber to the lower portion of the container. In practice, the mercury in the container *A* is heated to, and maintained at, a temperature below its boiling point, but above the boiling point of water. When water is injected through the nozzle *H* from the pipe *J*, the injecting action of the jet of water induces hot mercury to flow from the container, through the tubes *B* into the axial tube *C*. Since the mercury is at a temperature above that required to cause water to boil, the water issuing from the nozzle, in mixing with the mercury, is flashed into steam, which rises up through the axial tube along with mercury. The formation of steam bubbles in the mercury causes swelling of the mercury, which rises into the separator and flows through the coiled tube *D* of the separator. The swirling of the mixed steam and mercury in the separator tube permits the steam to issue through the orifices *E* while the mercury remains within the tube *D*, from the open end of which it runs into the bottom of the steam chamber. The steam passes out of the chamber *F* through the pipe *G*, and the cooled mercury passes down the return tubes *L* into the lower portion of the container where it is again heated.—*July* 2, 1952.

AERONAUTICAL ENGINEERING

635,842. (Amended). June 5, 1947.—AIRCRAFT LANDING GEAR, Electro-Hydraulics, Ltd., of Liverpool Road, Warrington, Lancashire, and Christopher Bernard Vere Neilson, of Gove House, Fearnhead, Lancashire, and Richard George Hoare, of 6, Winmarleigh Street, Warrington, Lancashire.

Referring to the drawing, pivotally connected to the leg *A* by the axle *B* is the bogie frame *C* carrying four wheels. The back brake plates of the front wheels *D* are connected to the bogie *A* in such a way that they cannot move relative to it. The brake back plates of the rear pair of wheels *E* are fitted on a bearing surrounding the axle or axles carrying the rear wheels, and are free to rotate relative to the bogies and the brake drum of the wheels. The rear brake back plates are coupled by pins *F* to the links *G*, which are connected by pins *H* at their ends to the arms or levers *J*, which in turn are fixed by dowels to the main axle of the bogie and cannot move relative to it. In the arrangement the brake torque on the rear brake back plates transmitted through the brake shoes will apply tension in the link *G* for one direction of movement of the aircraft, when travelling from right to left, and since this link is coupled to the arm *J* fast with the axle, it provides the necessary reaction to counteract the anti-clockwise tilting



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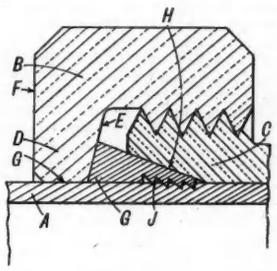
torque or moment on the bogie frame member. If the movement of the aircraft is in the opposite direction, from left to right, the rear brake back plates will apply compression in the link *G* and tend to reduce the vertical load on the rear wheels, thus maintaining the ground pressure uniform on all wheels. For any known rolling radius of the tyres of the wheels the distance between the wheel axles and the point of coupling the link *G* to the rear brake back plates can be so selected that on applying the brakes, the loads on the bogie give no moment about the axle, and the frame member does not tend to tilt. In an alternative arrangement the rear brake back plates may be fixed and the front wheel brake back plates be similarly connected to the arm or lever *J*.—*July* 2, 1952.

TUBE AND PIPE COUPLINGS

675,082. November 20, 1950.—PIPE COUPLINGS, Frank Kay, of "The Elms," Clifton Drive, Lytham, Lancashire.

In the drawing, *A* is a pipe and *B* is a coupling nut which screws on to the coupling body *C*. The nut has a circumferential flange *D* with an inner face *E* set at an acute angle with respect to the right



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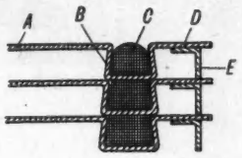
angular outer face *F*. This face *E* forms a pressure-applying surface and is adapted to abut against the thick end of the wedge-shape sealing thimble *G* when the nut is screwed on to the body, forcing the thimble into the flared mouth of the body *C*. The combination of the surface *E* and the taper of the mouth *H* causes a radial force to be exerted as the thimble is moved axially into the mouth, and the internal diameter of the thimble is pressed tightly on to the pipe *A*. The desired seal and bearing support is provided by a number of metal piercing ridges *J* which are formed continuously around the internal diameter of the thin end of the wedge thimble. With the pipe in position and the coupling tightened as shown, the relatively sharp ridges *J* are forced into the pipe wall, which, as shown, partially enters the triangular recesses between the ridges. When the pipe has exerted against it a high internal pressure, the shape of the recesses and the surface act as a rigid support against the pipe wall being forced outwards; this produces a strong buttress formation which holds the pipe and enables a high internal pressure to be withstood.—*July* 2, 1952.

HEAT EXCHANGERS

674,906. January 24, 1950.—PLATE HEAT EXCHANGERS, Charles Zeuthen, Richard Zeuthen and Martin Larsen, trading as Silkeborg Maskinfabrik, of Silkeborg, Denmark.

The invention relates to plate heat exchanging apparatus embodying thin plates, of stainless steel, with a depressed slot or groove along the edge to accommodate the packing. Referring to the drawing, *A* is a heat exchanging plate, having a



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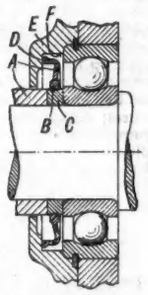
packing slot *B* with an inserted packing *C*. Outside its outer side is a plate section *D* on which is mounted an angle iron *E*. It is mechanically desirable to solder the angle iron *E* somewhat inside the outer edge of the plate *D* as shown.—*July* 2, 1952.

SEALING DEVICES

675,146. May 15, 1950.—OIL-SEALING DEVICES FOR ROTATING SHAFTS, Société à Responsabilité Limiteé Sobeba, of Rue d'Angers, Courbevoie, Seine, France.

The oil-sealing member *A* described in the specification is made of a thermoplastic material with a high elasticity, such as a superpolyamide. It is provided with an internal circular aperture which is surrounded by an enlarged portion *B*, which is shown as moulded on the periphery of a metal ring



No. 675,146

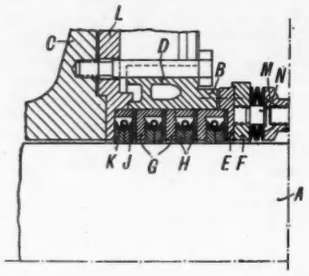
C. It comprises a flat circular portion lying in a plane perpendicular to the axis of the shaft and it has an outer portion of a short length bent at substantially 90 deg. and terminating in a peripheral edge, beaded as indicated at *D*. In the mounting shown a shaft is supported by a ball bearing within a gear case. The ball bearing is clamped against a shoulder of the shaft by a tubular stay pressed axially by a nut. The ring *C* is clamped between the stay and the inner race of the ball bearing. The mounting further comprises a cover *E* having a recess *F* which forms a housing for the member *A*. The peripheral beaded edge *D* of the member bears against the ground bottom of recess *F* under the action of elasticity of the member, which is slightly deformed. Under these conditions the peripheral edge ensures a tight joint against the bottom of the recess *E* and prevents any oil leakage either during rotation of the shaft or at standstill. The device, it is claimed, operates more or less like the known packing members of refrigerating compressors, but with a much simpler arrangement, comprising no intermediate elastic member and no loading spring.—*July* 2, 1952.

INTERNAL COMBUSTION ENGINES

675,074. July 12, 1950.—STUFFING-BOXES FOR PISTON-RODS OF LARGE GAS ENGINES, Maschinenfabrik Augsburg-Nürnberg A.G., of Nürnberg, Germany.

As shown in the drawing, the piston-rod *A* of a high-powered gas engine with two double-acting cylinders arranged in tandem is made gas-tight at each of the inwardly lying cylinder ends by means of a stuffing-box *B* mounted on the cylinder cover *C*. Each stuffing-box consists of a casing *D*, gland rings *E* and *F*, and sleeve rings *G*, forming chambers enclosing packing rings *H* and provided with radial flanges. These components can be removed and replaced without having to withdraw

the rear cylinder. Over the packing rings are provided divided protecting rings *J* for tubular springs *K*, which press them against the piston-rod. The casing is inserted in an intermediate piece *L* of the cylinder cover and is fixed to it by headed screws



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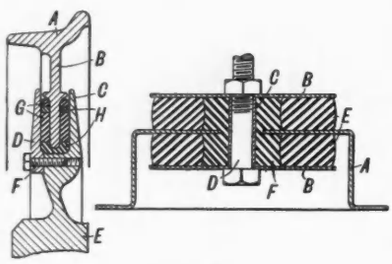
laid in semi-circular grooves at the periphery of the casing. The stuffing-box casing is supported by screw strut devices *M*, each comprising studs *N* and screwed into the gland rings of the respective stuffing-boxes. The studs are threaded, a long nut having an enlarged end being screwed on the stud with a disc spring encircling it. The enlarged end of the nut acts as one abutment for the springs, the other abutment being formed by the gland ring *F* in which the stud is screwed. Modified designs are also shown in the specification.—*July* 2, 1952.

RESILIENT SUPPORTS

674,762. September 25, 1948.—Resilient Mountings, The Dunlop Rubber Company, Ltd., of 1, Albany Street, London, N.W.1, and Geoffrey William Trobridge, Robert Maxwell Seddon and Paul Brierley, of the company's works at Erdington, Birmingham, 24.

This invention relates to resilient wheels wherein elements of natural rubber or the like are interposed between the rim and the hub. The wheel shown in the left-hand drawing comprises a rim *A* having



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a flange *B* which lies between the arms *C* and *D* of an annular channel. The arm *C* is integral with a hub *E* and the arm *D* is bolted to it by a number of bolts *F*. The rim is resiliently connected to the hub by vulcanised rubber annuli *G*, and damping is provided by annuli *H* made of an unvulcanised rubber composition. Both sets of annuli are precompressed between the adjacent faces of the flange and channels. The mounting shown in the right-hand drawing comprises a supporting member *A* of circular shape, two annular plates *B*, a cylindrical spacer *C*, a nut and bolt *D*, two annular vulcanised rubber elements *E*, and a mass *F* of unvulcanised rubber located between the plates, spacer and rubber elements. The rubber is precompressed between the plates *B* by the nut and bolt *D*. Resilient mountings in which the rubber operates under shear are also described in the specification.—*July* 2, 1952.

Ports Efficiency Committee.—As a result of the work of the Ports Efficiency Committee, ports operations panels consisting of representatives of port authorities, shipowners, port employers and labour have been set up at the main British ports with the object of ensuring the most effective use of equipment and of dock labour. A parallel set of committees, known as the Port Users' Committees, has been set up at the instigation of the Federation of British Industries, the Chamber of Shipping and other shipping interests, and they will be complementary to the Ports Operations Panels.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the TIME and PLACE at which the meeting is to be held should be clearly stated.

Association of Special Libraries and Information Bureaux

Fri. to Mon., Sept. 19th to 22nd.—The Hayes, Swanwick, Derbyshire, Twenty-seventh Annual Conference.

British Association for the Advancement of Science

Wed. to Wed., Sept. 3rd to 10th.—Annual Meeting in Belfast.

Engineers' Guild

Thurs., Sept. 25th.—Caxton Hall, Caxton Street, Westminster, London, S.W.1, Annual General Meeting, 6 p.m.

Institute of Road Transport Engineers

Wed., Oct. 1st.—Royal Society of Arts, John Adam Street, London, W.C.2, Annual General Meeting, 6.30 p.m.

Institution of Mining and Metallurgy

Tues. to Thurs., Sept. 23rd to 25th.—Imperial College of Science and Technology, Prince Consort Road, South Kensington, London, S.W.7, Symposium on Mineral Dressing.

International Machine Tool Exhibition

Wed. to Sat., Sept. 17th to Oct. 4th.—Olympia, London.

Contracts

Modern Wheel Drive, Ltd., Stanley Avenue, Chesham, Bucks, has received an order for two oil-operated reverse-reduction gears for installation with National Supply (Ohio) engines in a heavy-duty tow-boat for the Dravo Corporation Union Barge Line. The gears will each transmit 2000 b.h.p. at 600 r.p.m. with a propeller speed of 220 r.p.m. in "ahead" and 233 r.p.m. in "astern."

The British Tanker Company has placed an order for seven tankers, each of 32,000 tons deadweight and having the following particulars:—Length, 675ft; beam, 86ft; summer draught, 35ft.; and double reduction geared turbines of 14,000 s.h.p., to give a service speed of 15½ knots. Two ships have been ordered from John Brown and Co., Ltd., and the following firms are to build one each:—Cammell Laird and Co., Ltd., Harland and Wolff, Ltd., Belfast; Hawthorn, Leslie and Co., Ltd.; Swan, Hunter and Wigham Richardson, Ltd.; and Vickers-Armstrongs, Ltd., Barrow.

The Crown Agents for the Colonies, on behalf of the Nigerian Government, have placed a contract with Dorman Long and Co., Ltd., Middlesbrough, for a suspension bridge over the Cross River, Nigeria. The site of the bridge, which will carry the only road joining the Eastern Provinces of Nigeria to the British Cameroons, is about 120 miles from the West African Coast. The overall length of the bridge will be 590ft and the main span over the gorge through which the Cross River flows will be 350ft. The deck will be 90ft above normal low water level. The value of the contract, which will require 500 tons of steel, is £315,000. The consulting engineers are Messrs. Coode and Partners, of London.

Launches and Trial Trips

City of Exeter, passenger and cargo liner; built by Vickers-Armstrongs, Ltd., Walker Naval Yard, for Ellerman Lines, Ltd.; length between perpendiculars 500ft, breadth moulded 71ft, depth moulded to upper deck 41ft, load draught 28ft 6in, deadweight 10,760 tons; 106 passengers, service speed 16½ knots; two Hawthorn-Doxford oil engines, six cylinders, 670mm diameter by 2320mm combined stroke, heavy fuel, total b.h.p. 12,650 at 115 r.p.m., two thimble-tube boilers, three 400kW diesel generators. Launch, July 7th.

Janita, oil tanker; built by Harland and Wolff, Ltd., for Anders Jahre and Co., Norway; a sister ship of the "Janova." Trial, July 8th.

Sibella, oil tanker; built by the Furness Shipbuilding Company, Ltd., for Skibsaktieselskabet Avanti, Norway; length between perpendiculars 560ft, breadth moulded 80ft, depth moulded 42ft 3in, deadweight 24,550 tons on 32ft 3½in summer draught, trial speed 14 knots; N.E.M.-Doxford oil engine, six cylinders, 670mm diameter by 2320mm combined stroke, 6800 b.h.p. at 116 r.p.m., two Scotch boilers, one 150kW steam-driven generator, two 250kW diesel generators. Launch, July 8th.

Vanessa, steam trawler; built by Cook Welton and Gemmell, Ltd., for the Atlas Steam Fishing Co., Ltd.; length between perpendiculars 178ft, breadth moulded 31ft, depth moulded 16ft, gross tonnage 675; fish room 14,925 cubic feet; machinery supplied by C. D. Holmes and Co., Ltd.; one set of triple-expansion engines, cylinders 15½in by 26in, 43in by 27in stroke, one oil-fired multi-tubular boiler. Launch, July 10th.

Cherbourgeois No. 5, tug; built by Les Chantiers et Ateliers Augustin Normand for La Societe Cherbourgeoise de Remorquage et de Sauvetage; length between perpendiculars 37m, breadth moulded 9m, depth 4·4m, draught 3·77m, displacement 672 tons; one electric motor of 1500 h.p. at 150 r.p.m. is supplied with power by two generators driven by M.A.N. diesel engines, speed, 12 knots. Launch, July 10th.

Books Received

Mechanical World Year Book, 1952. Sixty-fifth edition. Manchester: Emmott and Co., Ltd., 31, King Street West. Price 3s. 6d.

Introduction to Electronic Circuits. By R. Feinberg. London: Longmans Green and Co., 6–7, Clifford Street, W.1. Price 18s.

Carburation. Vol. II. Third edition revised. By C. Fisher. London: Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 36s.

Steels in Modern Industry. By W. E. Benbow. London: Iliffe and Sons, Ltd., Dorset House, Stamford Street, S.E.1. Price 42s.

P.L.A. Railways. By Thomas B. Peacock. London: The Locomotive Publishing Co., Ltd., 88, Horseferry Road, S.W.1. Price 15s.

The Non-Destructive Testing of Metals. By R. F. Hanstock. London: The Institute of Metals, 4, Grosvenor Gardens, S.W.1. Price 21s.

Prism and Lens Making. By F. Twyman. London: Hilger and Watts, Ltd., Hilger Division, 98, St. Pancras Way, N.W.1. Price 58s.

Industrial High Vacuum. By J. R. Davy. London: Sir Isaac Pitman and Sons, Ltd., Parker Street, Kingsway, W.C.2. Price 25s.

"Hutte" Taschenbuch Fur Betreigsingenieure. London: Lange, Maxwell and Springer, Ltd., 41–45, Neal Street, W.C.2. Price 36 Dmk.

Werkstattbucher: Der Elektrische Antrieb von Wekzeugmaschinen. By H. Birett. Berlin: Springer-Verlag, Berlin. Price 3.60 Dmk.

Railway Motive Power. By Harry Webster. London: Hutchinson's Scientific and Technical Publications, Stratford Place, W.1. Price 30s.

Rockets, Missiles and Space Travel. Second edition. By Willy Ley. London: Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 30s.

Architecture as a Career. By Maurice E. Taylor. London: Iliffe and Sons, Ltd., Dorset House, Stamford Street, London, S.E.1. Price 10s. 6d.

Theorie et Practique des Travaux a la Mer. By Marcel Blosset. Paris: Marc Eyrolles, 61, Boulevard Saint-Germain, Paris (5e). Price 3950 francs.

The Wire Industry Encyclopædia Handbook, 1952. Second edition. London: The Wire Industry, Ltd., 33, Furnival Street, E.C.4. Price 21s.

Theory of Perfectly Plastic Solids. By William Prager and Philip G. Hodge, Jr. London: Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 44s.

Earthing Principles and Practice. By R. W. Ryder. London: Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, W.C.2. Price 15s.

The Displacement Method of Frame Analysis. By G. P. Manning. London: Concrete Publications, Ltd., 14, Dartmouth Street, Westminster, S.W.1. Price 9s.

Protection and Electro-Deposition of Metals: Vol. 3. London: Department of Scientific and Industrial Research, Lacon House, Theobalds Road, W.C.1. Price 30s.

The Electrician Blue Book, 1952. Edited by Stanley G. Rattee. Seventieth edition. London: Ben Brothers, Ltd., Bouverie House, 154, Fleet Street, London, E.C.4. Price 50s.

Pocket Technical Encyclopædia. Compiled by L. E. C. Hughes and Jean P. Bremmer. London: Hutchinsons' Scientific and Technical Publications, Stratford Place, W.1. Price 7s. 6d.

Microphones. By the Staff of the Engineering Training Department, British Broadcasting Corporation. London: Iliffe and Sons, Ltd., Dorset House, Stamford Street, S.E.1. Price 15s.

Hydrodynamische Grundlagen, zur Berechnung der Schiffsschrauben. By Dr.-Ing. M. Stracheletzky. Germany: Verlag G. Braun, Karlsruhe i.B. Karl Friedrich Strasse 14, Baden. Price 12 Dmk.